DOCUMENT RESUME

ED 112 845 IR 002 551

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TITLE A Procedure for Quantification of Technological Changes on Human Resources.
INSTITUTION Air Force Human Resources Lab., Brooks AFB, Texas.
REPORT NO AFHRL-TR-75-33
PUB DATE Jun 75
NOTE 93p.

EDRS PRICE MF-$0.76 HC-$4.43 Plus Postage
DESCRIPTORS *Behavioral Science Research; Decision Making; Design Preferences; Evaluation Criteria; Evaluation Methods; *Human Resources; Man Machine Systems; Measurement Techniques; *Prediction; Problem Solving; *Psychological Evaluation; *Technological Advancement; Testing
IDENTIFIERS *Design Option Decision Trees

ABSTRACT

To assist the human factor psychologist in predicting the human resources requirements based on the introduction of a new technology, a study was conducted to locate and apply an existing method, or to develop a new procedure for quantifying the effects of incoming technology. Five steps were taken: search and critical analysis of recent literature; development of Design Option Decision Trees (DODT) describing two Air Force systems; synthesis of existing techniques to develop a procedure; and evaluation of the procedure's feasibility. A methodological procedure integrating the DODT with a modification of the method of summated ratings was developed as a feasible approach for measuring the effects of advances of technology. (SK)

AFHRL-TR-75-33

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AIR FORCE

HUMAN RESOURCES

A PROCEDURE FOR QUANTIFICATION OF TECHNOLOGICAL CHANGES ON HUMAN RESOURCES

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This interim report was submitted by Systems Research Laboratories, Inc., 2800 Indian Ripple Road, Dayton, Ohio 45440, under contract F33615-74-C-4019, project 7907, with Advanced Systems Division, Air Force Human Resources Laboratory (AFSC), Wright-Patterson Air Force Base, Ohio 45433. Major Duncan L. Dieterly, Personnel and Training Requirements Branch, was the contract monitor.

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This technical report has been reviewed and is approved.

GORDON A. ECKSTRAND, Director
Advanced Systems Division

Approved for publication.

HAROLD E. FISCHER, Colonel, USAF
Commander

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
AFHRL-TR-75-33

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
A PROCEDURE FOR QUANTIFICATION OF TECHNOLOGICAL CHANGES ON HUMAN RESOURCES

5. TYPE OF REPORT & PERIOD COVERED
Interim (Special Subject Event)

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
Norman R. Potter
Kenneth D. Korkan
Duncan L. Dieterly

8. CONTRACT OR GRANT NUMBER(s)
F33615-74-C-4019

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Systems Research Laboratories, Inc.
2800 Indian Ripple Road
Dayton, Ohio 45440

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
79070007

11. CONTROLLING OFFICE NAME AND ADDRESS
Hq Air Force Human Resources Laboratory (AFSC)
Brooks Air Force Base, Texas 78235

12. REPORT DATE
June 1975

13. NUMBER OF PAGES
90

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
Advanced Systems Division
Air Force Human Resources Laboratory
Wright-Patterson Air Force Base, Ohio 45433

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

technology forecast
human resources parameters
prediction methods
human resource prediction
technology impact
technology chance
summated ratings
decision options

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A long standing research objective of the human factors psychologist has been the capability to predict the human resource requirements of new equipment. An even more intriguing problem is the prediction of human resource requirements based on the introduction of a new technology. The purpose of this study was to locate and apply an existing method, or to develop a new procedure for quantifying the effects of incoming technology. A five-step approach was taken in an attempt to achieve the research goal. These steps included search and critical analysis of the recent literature to review the status of forecasting and assessing technology, and of techniques for predicting the impact of technology on human resources; development of Design Option Decision Trees (DODT)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Item 20 Continued:

describing two Air Force systems; synthesis of existing techniques to develop a procedure for measuring the effects of technology on human resources; application of the procedure; and evaluation of the feasibility of the evolved procedure.

A procedure integrating the DODT with a modification of the method of summated ratings was developed to permit quantification of specific human resource components at each of the design options represented in the DODT. Using judgmental data collected from an Air Force operational unit, the method developed under this study effort was evaluated. It was concluded that quantifying human resource components associated with hardware design options by means of a technique incorporating a DODT and a modification of the method of summated ratings was a feasible approach and could provide one methodological procedure for measuring the effects of advances in technology on human resources.

SUMMARY

PROBLEM

The purpose of this study was to develop, apply, and evaluate the feasibility of a procedure for measuring the effects of technology on human resources. Interest was centered on development of a tool for use by system designers and manpower planners which would permit the specification, in advance of system development, of the effects of a technological innovation on the human resources required to interact in the operation and maintenance of the system.

APPROACH

A normative forecasting procedure known as a Design Option Decision Tree (DODT) was employed to graphically depict the sequence of engineering decisions in complex weapon systems. The technological design options available at each of the decision points were established for two Air Force systems, Remotely Piloted Vehicle and Digital Avionics Information Systems. With the DODT it was possible to classify the level of technology represented among the options into examples of state-of-the-art, incoming or advanced technology.

Emphasis of this research effort has been directed toward a concentration on analysis of the Digital Avionics Information System (DAIS). This emphasis served to dictate to a large degree the data sources available for analysis. As a DAIS configured weapon systems does not presently exist in the Air Force inventory, maintenance personnel on the A-7 weapon system, which does include some digital avionics, were selected as judgmental experts for the data source in this study. Judgmental data were collected from the maintenance personnel on a series of selected human resource parameters. Judgmental data were collected as the analysis base for this effort.

Three classes of data were included in the analysis: first, human resource components; second, the hardware decision options; and third, selected background and experience information on the technicians who served as the source of the data.

The human resource components included in this study were:

- Worker Preference
- Desirability of Written Procedural Manuals
- Level of Skill Required
- Difficulty Level of Task
- Extent of Training Required
- Environmental Effects on Maintenance
- Amount of Time Required for Maintenance

The data collected were statistically analyzed with t-tests, analysis of variance, multiple range test and correlation matrixes.

RESULTS AND CONCLUSIONS

For the seven resource components selected for feasibility study, the survey results indicate that four of the components, i.e., worker preference, skill level required, difficulty level of task, and time required to maintain or troubleshoot impacted significantly in half or more of the decision point/option alternatives sampled. Further, the options available at three of the decision points studies appeared to have the heaviest impact on the human resource components under investigation. These decision points impacting on four or more of the human resource components were: the choice of single or multiple multiplex data buses for the system; the commonality of LRU processors; and the type of software structure.

The data served to support the contention that technological choices made during the design process will have varying degrees of impact on human resource parameters. In addition those technological choices which appear to have a strong impact on human resource parameters may impact only on certain parameters and not on all parameters. The degree of technological impact is dependent upon the human resource parameter or set of parameters of interest. The methodology developed in this study was generally acceptable to the respondents. It provided an initial step in attempting to predict the impact of new technology upon human resource parameters by reducing the design process to a series of decision points which could be judged by field experienced technicians in terms of the human resource parameters selected.

PREFACE

This study was initiated by the Advanced Systems Division, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio, under Project 7907, Conditions of Effective Training and Transfer, Dr. Ross Morgan, Project Scientist; Work-Unit 79070007, Determining Impact of New Technology on Air Force Human Resources, Duncan L. Dieterly, Major, USAF, Task Scientist. The research was performed by Systems Research Laboratories, Inc., Dayton, Ohio, under Contract F33615-74-C-4019 with Dr. Norman R. Potter as principal investigator, and Kenneth D. Korkan as associate principal investigator.

The authors wish to acknowledge the guidance and support provided by Dr. William B. Askren and Kenneth W. Potempa of the Personnel and Training Requirements Branch, Advanced Systems Division, in initial structuring of the research problem.

Appreciation is expressed to Ned H. Kearns and George W. Watts of Systems Research Laboratories for their capable assistance in conducting the field survey at Myrtle Beach AFB, SC.

Finally, appreciation is extended to Tactical Air Command for permission to conduct the survey at Myrtle Beach AFB, SC, and especially to the technicians of the 354th Avionics Maintenance Squadron who participated as subjects in the maintenance survey.

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INTRODUCTION AND BACKGROUND

Historically man's propensity to predict the future can be documented from the prohetic, Oracle of Delphi through the fiction of Jules Verne, into the scientific realm of concern after the second world war. The emphasis on establishing future plans, both governmental and industrial, caused an upsurge of interest in forecasting change. (Clarke, 1969). The initial technique of forecasting consisted in the projections made by experts in a given field. This technique has given way to the development of more precise methods less dependent upon individual genius and more dependent upon scientific precepts.

The emergence of the discipline of technological forecasting in the past decade is an indication of the requirement to be able to estimate future situations in order to plan appropriately. While technological forecasting has usually addressed the impact of new technological concepts on hardware configurations and utilization, it could also be used to project human resource requirements. In the Armed Services and especially the Air Force, an interest in linking technological advancements and manpower requirements can be found in the process of building new weapon systems. Through the Air Force System Program Offices (SPO's), the management of the development of a new weapon system is maintained. Within this management system a formal projection is made in terms of the personnel and training required to operate and maintain the system.

A capability to relate the discipline of technological forecasting to the more narrow concern of human resource requirements for a weapon system

appears to be feasible at this time. By developing an amalgam of the two, a methodology could be developed to predict the impact of innovations in technology on the human resource requirements for a given system. This methodology would be of value to the armed forces but would also be useful for anyone interested in determining the impact upon human resources of a new technology.

From the recent past one of the major problems along these lines has been the concern with the effect of automation on human resources.

The most severe problem was encountered in the area of determining the effects of increasing automation on human resource parameters. In consort with all human resource components reviewed, no workable method of quantification was found. Additionally, as strongly asserted by an authority in the field, in spite of 20 years study of the problem, a categorical statement concerning the effect of automation on skill requirements cannot be made (deGreene, 1974). This same author concluded that, ". . . it will probably be years before a predictive, or even an explanatory, theory of technical change is developed." The shortcomings of the present capability in the area of quantification of technology impact on human resource components has been reported (Potter and Dieterly, 1974).

In the search for a means of forecasting and assessing technology the result was more positive. The recent literature supported the use of a normative approach to forecasting. Of the available normative techniques to forecasting, the conclusion was reached that a modification of the relevance tree approach (Cetron, 1969), known as a Design Option Decision Tree (DODT) (Askren

and Korkan, 1971) would provide a means of graphically depicting the sequence of engineering decisions required and the design options available at each of the decisions points in a system design process. The DODT is a method for locating all decision points within a system. Thus, those decision points within a system which represent new technologies can be identified on the basis of expert judgment and assigned a position within the tree, as well as graphic reflection of those decision points which depict proven hardware technology options.

The goal of this research effort was the establishment of methods or techniques for determining and defining, in advance of system application, the components of an incoming technology and measuring the effects of that technology on human resource parameters. The impact and change on the operation and maintenance of a system which incorporates such a technology was the major consideration.

One of the most striking characteristics of technological forecasting is that there is no standard method for determining what constitutes a "new technology." In the literature a "new technology" may range from a process for producting some component to the use of a new component. In this research effort, this problem was recognized but not solved. The new technology in this effort was reduced to types of options made at design decision points. Some of the options were not as innovative as others, therefore the new technology introduced at the decision point varies considerable.

Points of a selected Design Option Decision Tree (DODT) were chosen to represent the variance of the technology concerned. The use of the DODT to identify a set of decision points appeared to be a reasonable approach to controlling the size of the new technology. At each decision point options are available which range from previously used options to new options which introduce the use of a new technology. The unit of new technology varies across the set of decision points selected but each decision point has approximately equal weight in the design process.

INTRODUCTION TO HUMAN RESOURCE COMPONENT QUANTIFICATION EFFORTS

The dearth of established techniques for acceptable quantification of human resource parameters in man/machine systems became apparent in the Potter and Dieterly (1974) review of recent literature. There is no method that has been shown acceptable for the detailed prediction of the effects of an incoming technology on the human resources required to interact with that technology.

The goal underlying this human resource component quantification effort was to develop unique scalar methods for measuring the effects of a specific forecasted technology on Air Force human resources. In this study, as an interim step toward achievement of quantification of the effects of technology, judgmental data was collected to serve as an analysis base. This data base was used to seek insights for future directions to be followed in joining objective quantification procedures with the Design Option Decision Tree technique.

The selection of the specific human resource components for study was guided by two primary concerns. First, an assessment of the ability to obtain judgmental data from field personnel in operational units. With this selection criterion, seven human resource components were chosen for use in a feasibility demonstration of the quantification procedure proposed.

The human resource components viewed as amenable to data collection were:

- Worker preference
- Desirability of written procedural manuals
- Level of skill required
- Difficulty level of task
- Extent of training required
- Environmental effects on maintenance
- Amount of time required for maintenance

The second area of concern was that the human resource components chosen for study would allow meaningful questions to be asked at each decision point in the DODT to which they were applied.

METHODS OF QUANTIFICATION

The term "quantification" can be regarded as being synonymous with measurement, the act of pairing of the members of two sets. This process of matching an event to some scalar value implicitly depends on knowledge of the appropriate underlying relationship between the component and the quantizing scheme.

The techniques for arriving at a definition of this relationship have remained undefined for all except the most gross statements of association. These gross association predictions are more of the type referred to by Stevens (1957) as metathetic. In essence, they deal only with nominal quantification (qualification), not with scalar expression.

With quantification defined as a process of matching the elements of two sets, a number of procedures for accomplishing this matching task are possible. In this section, consideration will be given to the generic methods available and the possibility of application of each to the present task will be discussed.

For practical utility in objective impact decisions on advanced systems, the decision makers must have access to at least an ordinal scale. The attributes of such a scale represent the minimum requirement for defining in advance a "best design option." As indicated earlier in this paper, those methods of quantification found in the current literature are of little applicability as they are, for the most part, representative of nominal quantification.

Ideally, to function in the area of trade-off analysis, the design engineer requires access to a ratio scale. While this is possible for certain considerations--a wing surface with zero lift is conceivable--in the area of human resources, few components are capable of ratio scaling. Illustration of this fact can be quickly provided by attempting to conceive the state represented by zero intellectual capability, or, more practically for this

paper, of zero mechanical aptitude. Though the ideal of ratio scaling is infrequently satisfied, trade-off studies are still performed. In such an instance, the components of variables evaluated are not quantified in comparable units, but the individual conducting the trade-off study must take action as if they were.

In an attempt to compensate for this lack of comparability across variables being treated, an attempt has been made to develop a standardized quantification scheme for the seven human resource components included in the set upon which judgmental information was collected to serve as the data base for analysis. Details of this attempt will be presented in the next section of this paper.

Of the methods of quantification available to the researcher, certain of the more fundamental ones can be rejected for the purposes of this study. The method of average error, the method of limits, and the method of frequencies, all fundamental psychophysical methods, are concerned with measuring or evaluating one stimulus. While they can be used in scaling, there is considerable inefficiency introduced in the number of observations required. These methods were therefore rejected for application.

The quantification methods discussed below are generally regarded as being better suited to scalar applications than are the more fundamental psychophysical procedures. For each method, selected advantages and reasons for consideration or rejection are given.

First, the method of paired comparisons is perhaps the most popular of the techniques of psychological scaling. A reason for its popularity may well lie in the fact that this procedure does not force transitivity on the data (Torgerson, 1958). However, the nature of the judgmental task in the present effort was not amenable to the use of a decision procedure about a pair of stimuli presented for comparison. For this reason, the method of paired comparisons was eliminated from further consideration.

The method of rank order holds certain attractions over the method of paired comparisons. It reduces subject time yet is equivalent to the method

of paired comparisons (Thurstone, 1931). However, like the method of paired comparisons, this procedure also involves the judging of a number of stimuli with reference to one another. Thus, this method was not considered appropriate to the judgmental task in this study.

The methods of interval and ratio judgments require more rigid assumptions than do the other psychological scaling techniques. The task asked of the observer in this instance is to compare the size of the intervals between stimuli rather than to make direct judgments about the stimuli themselves. Subsummed under this type of scaling is the method of equal-appearing intervals of Thurstone and Chave. Under this method it is possible to directly apply an interval scale to the set of stimuli being evaluated. As the nature of the present measurement task is not to separate n number of stimuli into a fixed number of locations separated by equal sense distances, this method of scaling is also found to be inappropriate to the task.

Within the methods of interval and ratio judgment is included the method of constant sums. Under this scaling procedure, the respondent is required to assign numbers directly to the stimuli presented to him. Here the respondent is instructed to distribute among the stimuli presented to him a total number of points, usually 100, so that the strength of sensation of each of the stimuli can be equated to the number of points assigned to it. In this way the relationships between the stimuli can be evaluated. With this procedure the resulting judgments can be converted into a ratio scale. This method could have been used with the judgmental task in the present study, however other considerations caused it to be rejected. A strong reason leading to rejection was the length of time which would have been required for each respondent. The time availability of personnel of the 354th Avionics Squadron (TAC), Myrtle Beach AFB, S.C., dictated the selection of a procedure which would be the most productive in a minimal time. This method then was also rejected as a vehicle for data collection in this study, primarily on the basis of the time constraints.

The method of successive categories is a procedure of scaling which has found popularity and broad general usefulness in scaling problems as it

does not require that the respondent be able to classify into an interval scale. It is particularly useful where difficulty is expected in obtaining stable judgments with other methods. A procedure subsumed under this classification is the Likert technique frequently referred to as the method of summated ratings (Murphy and Likert, 1937; Edwards, 1957). Concern of this method is with the systematic variation of respondents to the stimuli presented. This variation is attributed to differences in the subjects. The immediate purpose of the method is to scale the respondents.

The Likert method of summated ratings was the procedure selected for use as a data collection vehicle. The reasons for this particular choice were many. Foremost among them was the relative speed of administration of such a scaling procedure. Secondly, the simplicity of the instrument itself permitted standardization across the human resource components selected for collection of data. Thirdly, the Likert technique typically shows higher reliability than do other methods of scaling (Edwards, 1957).

On the negative side, Torgerson (1958) maintained that the use of a "subject-centered approach has not yet led, to any great extent, to the development of scaling models." This comment is appreciated by the present authors; however, it is believed that the method of summated ratings, coupled with the use of the Design Option Decision Tree, will permit collection of baseline data leading to the development of predictive equations which can make possible the specification of the effects of a technological advance on the personnel required to operate and maintain a weapon system employing that technology.

PROCEDURE

The use of the DODT coupled with a modification of the method of summated ratings appears to be an appropriate combination that would lead to significant baseline data. Each decision point in a DODT reflects present state-of-the-art alternatives as well as incoming technological advances and predictable future technology. As an example, the choices concerning the memory in the Digital Avionics Information System (DAIS) DODT to be discussed in a later section of this report contain well known options such as core, disc, and tape. However, in addition to these choices there is also the semiconductor and bubble which are considered at the present time to be in the research and development stage. This type of technological spread among the options is present to some extent at each decision point in the DODT and is therefore inherent in the entire DODT. The respondent is able to evaluate these choices with respect to the questions asked based not only upon actual experience, but upon education and the inherent common interest of individuals involved in the field of digital avionics. Therefore, this procedure should elicit numerous resource component data of value as inputs to engineering design decisions for the system.

Rather than attempt to quantize the entire DAIS DODT, it was decided to utilize only selected design option decision points. This decision was dictated by the time constraints on the study, in addition to the exploratory nature of the task, i.e., the establishment and demonstration of the feasibility of a method that would yield useful numerical values.

Therefore, only eight decision points were selected for this study. The rationale used in the selection process was to choose those decision points in the system which portrayed a technical area with which the subjects would be familiar by virtue of experience or training. Decision points were selected to reflect varying states of technology. For certain decision points, well established technology was reflected by most of the available options. For other points, the options heavily expressed either incoming advances in technology or predicted future technological innovations but included established technology.

A further restriction imposed in selecting the decision points was that the design options at the points selected must lend themselves to human factor type questions dealing with maintenance and troubleshooting concepts.

The DAIS has been described by classifying the system into four functional areas referred to as core elements. These core elements are: processors, system programming, memory, and remote terminal units. In selecting the decision points and options for study, at least one decision point was selected in each core element of DAIS.

The DODT's portraying the DAIS consisted of a series of five sheets of decision options. (See Appendix A for an example). From these trees a sub-set of decision points were selected. The decision points selected were taken throughout the total set of trees to provide a representative sample of decision options.

Selecting at least one decision point in each core element permits a preliminary demonstration of the effects on one or more human resource parameters of the selection of various alternatives as one processes along a design path (see Figure 2).

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The DODT's protraying the DAIS design are shown in Appendix A (SRL Drawing Number 6810-02-2499, sheets 1 through 5). From these trees, the decision points identified below, by means of drawing number, sheet, and sheet location, were selected for application of the quantizing scheme:

SRL Dwg. No. 6810-02-2499 (Sheet 1 - D/7) "Information Processing (Overall System)"

SRL Dwg. No. 6810-02-2499 (Sheet 1 - F/4) "Information Processing (Overall System)"

SRL Dwg. No. 6810-02-2499 (Sheet 2 - E/9) "Information Processing (Processors)"

SRL Dwg. No. 6810-02-2499 (Sheet 2 - B/6) "Information Processing (Processors)"

SRL Dwg. No. 6810-02-2499 (Sheet 3 - D/12) "Information Processing (System Programming)"

SRL Dwg. No. 6810-02-2499 (Sheet 4 - F/13) "Information Processing (Memory)"

SRL Dwg. No. 6810-02-2499 (Sheet 5 - D/17) "Information Processing (Remote Terminal Unit)"

SRL Dwg. No. 6810-02-2499 (Sheet 5 - D/10) "Information Processing (Remote Terminal Unit)"

Selecting at least one decision point in each core element permits a preliminary demonstration of the effects on one or more human resource parameters of the selection of various alternatives as one processes along a design path (see Figure 2, page 34).

A set of seven questions was developed which could be posed of all eight decision points identified for data collection. Use of the same set of questions for each of the decision points was intended to create a standardized set in the technician for responses at each decision point. The decision points and their related design options were assembled in a booklet included as Appendix B. The format of the booklet was designed so that the technician being interviewed was able to observe the available design options while answering the questions. A Likert-type scale was associated with each question and the technician was asked to position his response in the form of a letter, i.e., A, B, etc., corresponding to the specific design option, along a continuum, essentially following the method of summated ratings. The results later were quantized by translation into interval scale points.

In addition to the questions involving maintenance/troubleshooting at the decision points, an information questionnaire was also included in the booklet. This was done to allow weighting factors to be applied to the collected data if necessary, taking into account such items as background, training, and experience of the technicians.

Since the present study involves digital avionics, it was decided to select an operational squadron in USAF Tactical Air Command (TAC) that utilized the A-7D aircraft for interview to obtain the data required. The choice of aircraft was consistent with the present DAIS activity at the Air Force Avionics Laboratory which involves components of the A-7 aircraft. After a survey of TAC squadrons that use the A-7 aircraft, the 354th Avionics Maintenance Squadron stationed at Myrtle Beach Air Force Base in South Carolina was chosen, with the concurrence of the Air Force. The interview effort was conducted from 5 through 9 August 1974.

The data that have been collected and quantized by the scheme mentioned earlier have been compiled into a special form, an illustration of which appears in Appendix C. A total of 32 subjects were interviewed thereby avoiding the use of small sample statistics during the analysis segment of this study.

In an attempt to standardize the data collection process, a written set of points to be covered was supplied to the interviewers. These points were verbalized to each respondent, or group of respondents, on those times when it was possible to survey more than one technician at once. Simplified examples of the procedure were discussed to provide a more complete understanding of the nature of the task the respondents were being asked to accomplish. A copy of the instructions to interviewers is included as Appendix D.

RESULTS

The subjects interviewed in this study, 32 in number, varied considerably with respect to age, background, and experience. However, as shown in Tables 1 and 2, the majority of the subjects were enlisted men whose age was 25 or below and whose grade was E3 or E4. The distribution of respondents has a significant effect on segments of the analyses that are described later. As would be expected, this skewed distribution is also observed in investigating areas such as total number of years in military/civilian service, total years of duty related experience, and the segment of the past five years applicable to the present duty assignment as shown in Table 3. However, it may also be noted that in addition to enlisted men, both officer and civil service personnel were also represented in the total sample thereby providing some subjects in the sample having a greater amount of experience both in background and age.

Subjects responses were solicited on 168 decision option/human resource component combinations. The number of responses obtained for each option ranged from 32 to 16, with the median number of responses at 31. The standardized set of questions was posed for each of the eight separate decision points in the survey. The code identification of each design option is listed in Table 4. These same codes are used to identify the decision options throughout the report.

For purposes of analysis, each response was assigned a numerical value along an eleven-point interval scale. Thus an integer value ranging from 0 through 10 was possible. Descriptive statistics (number responding, mean response value, standard deviation, and range) are given in Tables 5 through 11 for each of the design options and for each human resource component sampled.

In interpreting Tables 5 through 11, the reader should keep in mind that responses were made as a result of comparing the options located at a single decision point. Thus, for HRC 1 (Worker Preference) in Table 5, the statistics for decision point 1A should be compared with decision point 1B. The comparison being made here is the worker preference for troubleshooting

or maintaining a system employing a single multiplex data bus design as opposed to a multiple multiplex data bus configuration. In this example, a higher mean response favoring the single multiplex data bus configuration can be observed.

TABLE 1. MILITARY OR CIVILIAN RANK OF SUBJECTS IN MYRTLE BEACH AIR FORCE BASE SURVEY SAMPLE

Category	E3	E4	E6	E7	2nd Lt	GS11
USAF (Enlisted Men)	10	13	2	2		
USAF (Officers)					1	
Civil Service						4

TABLE 2. AGE OF SUBJECTS IN MYRTLE BEACH AIR FORCE BASE SURVEY SAMPLE

	Age						
Category	20 and Below	21-25	26-30	31-35	36-40	Above 40	Total
USAF (Enlisted Men)	6	16	1		4		27
USAF (Officers)			1				1
Civil Service			1		1	2	4
Total	6	16	3		5	2	32

TABLE 3. YEARS OF MILITARY/CIVILIAN SERVICE, YEARS OF DUTY RELATED EXPERIENCE, AND EXPERIENCE IN PAST FIVE YEARS APPLICABLE TO PRESENT DUTY ASSIGNMENT, FOR SUBJECTS IN MYRTLE BEACH AIR FORCE BASE SAMPLE SURVEY

	Time Span (Yrs)						
Area	Less Than One Year	1-4	5-8	9-12	13-16	16-20	Greater than 20
Total Number Years Military/ Civilian Service	4	19	1	1		6	1
Total Years Duty Related Experience	4	20	1	1	1	5	
Past Five Years Applicable to Present Duty Assignment	4	23	5				

TABLE 4. LISTING OF DESIGN OPTIONS AND ASSOCIATED CODE DESIGNATORS USED IN MAINTENANCE SURVEY CONDUCTED AT MYRTLE BEACH AFB, S.C., AUGUST 1974.

CODE DESIGNATION	IDENTIFICATION
1A	Single Multiplex Data Bus System
1B	Multiple Multiplex Data Bus System
2A	Shielded-Twisted Line Pair Bus
2B	Coax Bus
2C	Electro-optical Bus
2D	Other types of Bus
3A	Single Data Processor
3B	Multiple Data Processor
4A	No common processors at LRU level
4B	Some common processors at LRU level
4C	All common processors at LRU level
5A	Modular Structure Software
5B	Mixed Structure Software
5C	Tightly Packed Structure Software
6A	Core Memory
6B	Semiconductor Memory
6C	Disc Memory
6D	Tape Memory
6E	Bubble Memory
6F	Other types of Memory
7A	Remote Terminal Unit Serving One System
7B	Remote Terminal Unit Serving Several Systems
8A	Custom Designed Signal Modification Hardware
8B	Modular Design Signal Modification Hardware

TABLE 5. WORKER PREFERENCE (HRC-1) FOR DESIGN OPTIONS WITHIN EACH DECISION POINT SURVEYED, SAMPLE OF 32 TECHNICIANS, MYRTLE BEACH AFB, S.C. AUGUST 1974

Decision Point and Option	Number Responding	Mean Response	Standard Deviation	Range
1A	31	6.387	2.611	10
1B	32	4.781	2.758	10
2A	30	4.767	2.872	10
2B	30	2.067	2.235	8
2C	29	6.414	2.356	9
2D	20	6.100	1.895	6
3A	32	6.125	2.724	10
3B	32	5.156	2.659	10
4A	30	3.233	3.127	10
4B	32	4.750	1.541	6
4C	32	7.531	2.250	8
5A	32	6.500	2.979	10
5B	32	5.219	1.900	9
5C	32	4.125	2.678	10
6A	29	6.690	2.437	10
6B	29	5.404	2.205	9
6C	29	4.759	3.297	10
6D	28	4.750	2.836	10
6E	27	4.444	2.793	10
6F	19	5.368	1.952	8
7A	32	6.500	2.750	10
7B	32	4.750	2.449	10
8A	31	5.419	2.044	10
8B	31	6.804	1.856	6

TABLE 6. DESIRABILITY OF WRITTEN PROCEDURAL MANUALS (HRC-2) FOR DESIGN OPTIONS WITHIN EACH DECISION POINT SURVEYED, SAMPLE OF 32 TECHNICIANS, MYRTLE BEACH AFB, S.C., AUGUST 1974

Decision Point and Option	Number Responding	Response	Standard Deviation	Range
1A	31	8.161	1.667	5
1B	32	9.000	1.118	5
2A	30	7.600	2.154	6
2B	30	7.867	1.746	6
2C	29	8.517	1.632	6
2D	22	8.182	2.103	7
3A	32	8.281	1.625	5
3B	32	8.937	1.273	5
4A	31	8.065	1.740	5
4B	32	8.094	1.444	5
4C	31	8.161	1.588	5
5A	31	8.258	1.502	5
5B	31	8.452	1.562	5
5C	31	8.484	1.644	5
6A	29	8.414	1.498	5
6B	29	8.345	1.625	5
6C	29	8.276	1.436	5
6D	28	8.179	1.649	5
6E	26	8.577	1.472	5
6F	20	8.250	1.813	5
7A	32	8.000	1.750	8
7B	32	8.469	1.677	8
8A	31	8.677	1.228	5
8B	31	8.097	1.552	5

TABLE 7. LEVEL OF SKILL REQUIRED (HRC-3) FOR DESIGN OPTIONS WITHIN EACH DECISION POINT SURVEYED, SAMPLE OF 32 TECHNICIANS, MYRTLE BEACH AFB, S.C., AUGUST 1974

Decision Point and Option	Number Responding	Mean Response	Standard Deviation	Range
1A	32	5.806	2.039	8
1B	32	7.438	2.091	8
2A	31	5.003	2.570	9
2B	31	5.839	2.554	9
2C	30	6.733	2.175	8
2D	20	5.950	2.061	9
3A	32	6.437	1.676	6
3B	32	6.969	2.365	9
4A	30	7.533	2.320	10
4B	32	6.281	1.566	6
4C	32	4.656	3.068	10
5A	32	5.906	2.650	10
5B	32	6.437	1.853	10
5C	32	7.469	2.150	9
6A	29	5.655	2.656	10
6B	28	6.071	2.329	9
6C	28	5.750	2.198	9
6D	26	4.654	2.601	10
6E	25	7.440	1.961	5
6F	17	6.471	2.172	9
7A	32	6.094	2.323	9
7B	32	6.687	2.311	9
8A	31	6.742	2.501	10
8B	31	6.226	1.698	7

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TABLE 8. DIFFICULTY LEVEL OF TASK (HRC-4) FOR DESIGN OPTIONS WITHIN EACH DECISION POINT SURVEYED, SAMPLE OF 32 TECHNICIANS, MYRTLE BEACH AFB, S.C., AUGUST 1974

Decision Point and Option	Number Responding	Mean Response	Standard Deviation	Range
1A	31	4.419	2.211	8
1B	31	6.613	2.074	8
2A	31	5.419	2.721	10
2B	31	5.903	2.305	9
2C	30	6.667	2.371	8
2D	19	6.158	2.230	9
3A	32	5.600	2.424	10
3B	32	6.813	2.083	8
4A	30	6.967	2.549	10
4B	32	5.906	1.377	6
4C	32	4.531	2.817	10
5A	32	5.563	2.680	10
5B	32	6.281	1.441	5
5C	32	7.187	2.480	10
6A	29	5.172	2.890	10
6B	28	6.429	2.412	9
6C	28	5.500	2.625	10
6D	27	5.111	2.643	10
6E	25	7.480	1.746	5
6F	17	6.706	2.844	10
7A	32	5.344	2.313	9
7B	32	6.562	2.318	9
8A	31	6.774	2.210	9
8B	31	5.677	2.054	9

TABLE 9. EXTENT OF TRAINING REQUIRED (HRC-5) FOR DESIGN OPTIONS WITHIN EACH DECISION POINT SURVEYED, SAMPLE OF 32 TECHNICIANS, MYRTLE BEACH AFB, S.C., AUGUST 1974

Decision Point and Option	Number Responding	Mean Response	Standard Deviation	Range
1A	32	6.219	2.058	8
1B	32	6.969	1.992	8
2A	30	4.833	2.911	10
2B	30	5.333	2.547	9
2C	28	6.929	1.668	6
2D	18	6.389	1.860	7
3A	32	5.906	2.542	10
3B	32	6.906	2.037	7
4A	30	7.500	2.655	10
4B	32	6.031	1.447	6
4C	32	4.062	2.657	10
5A	32	5.969	2.038	10
5B	32	6.156	1.641	7
5C	32	6.813	2.674	10
6A	29	6.310	2.479	10
6B	28	7.036	2.442	9
6C	28	5.893	2.677	9
6D	27	5.481	2.672	10
6E	25	7.520	2.100	7
6F	17	6.824	3.091	10
7A	32	5.875	1.798	8
7B	32	6.531	2.106	9
8A	31	7.065	1.684	5
8B	31	5.774	1.963	9

TABLE 10. ENVIRONMENTAL EFFECTS ON MAINTENANCE AND TROUBLESHOOTING (HRC-6) FOR DESIGN OPTIONS WITHIN EACH DECISION POINT SURVEYED, SAMPLE OF 32 TECHNICIANS, MYRTLE BEACH AFB, S.C., AUGUST 1974

Decision Point and Option	Number Responding	Mean Response	Standard Deviation	Range
1A	32	6.344	2.056	9
1B	32	7.312	2.083	7
2A	30	5.900	2.925	10
2B	30	6.500	2.306	9
2C	28	6.393	2.193	8
2D	18	6.389	2.240	10
3A	32	6.406	2.691	10
3B	32	7.500	2.222	8
4A	30	7.600	2.525	10
4B	32	6.437	1.580	6
4C	32	5.031	2.628	10
5A	32	6.312	2.284	10
5B	32	6.781	1.866	6
5C	32	7.281	2.695	10
6A	29	6.655	2.467	9
6B	28	7.214	2.242	9
6C	28	6.786	2.258	8
6D	27	6.741	2.351	9
6E	25	7.520	2.100	7
6F	16	7.187	3.087	10
7A	32	6.156	2.539	9
7B	32	6.969	2.365	9
8A	31	6.645	2.222	8
8B	31	6.323	2.234	8

TABLE 11. TIME REQUIRED FOR MAINTENANCE OR TROUBLESHOOTING (HRC-7) FOR DESIGN OPTIONS WITHIN EACH DECISION POINT SURVEYED, SAMPLE OF 32 TECHNICIANS, MYRTLE BEACH AFB, S.C., AUGUST 1974

Decision Point and Option	Number Responding	Mean Response	Standard Deviation	Range
1A	32	4.938	1.952	8
1B	32	6.844	2.093	9
2A	30	5.367	2.822	10
2B	30	5.767	2.629	9
2C	28	5.714	2.033	9
2D	18	5.833	2.192	10
3A	32	5.531	2.436	10
3B	32	6.875	2.088	9
4A	30	7.367	2.858	10
4B	32	5.844	1.583	7
4C	32	4.156	2.635	10
5A	32	5.719	2.540	10
5B	32	6.562	1.580	6
5C	32	7.000	2.750	10
6A	29	5.586	2.312	10
6B	28	6.357	2.423	9
6C	28	5.536	2.337	9
6D	27	4.963	2.617	10
6E	25	7.440	1.982	7
6F	16	6.813	3.186	10
7A	32	5.469	2.634	9
7B	32	6.094	2.416	10
8A	31	6.613	2.120	9
8B	31	5.645	2.336	9

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In seeking to compare the pattern of response for the selected human resource components at the decision points chosen from the DAIS-DODT, it can be seen from Tables 5 through 11 that the choice at four decision points is limited to two options each. Thus, the hypothesis of no difference is testable by means of a two-sample t-test. Based on the assumptions of equal means and equal but unknown variances, this test was employed. The accept-reject decision at the 0.05 level of significance for each HRC/decision point so tested is shown in Table 12. This analysis revealed that 11 comparisons out of 28 would be interpreted as representing real differences in the human resource components involved. (The probability of such an occurrence is computed to be $P = 4.38 \times 10^{-8}$.)

TABLE 12. ACCEPT-REJECT DECISION FOR THE NULL HYPOTHESIS[†] RESULTING FROM COMPUTATION OF TWO-SAMPLE t-TESTS FOR THE HUMAN RESOURCE COMPONENTS AND DECISION POINTS SHOWN TOGETHER WITH THE PER CENT OF REJECTION OF THE NULL HYPOTHESIS FOR EACH HUMAN RESOURCE COMPONENT

HRC	Decision Points 1 (A,B)	3 (A,B)	7 (A,B)	8 (A,B)	Per Cent Rejection
1	R[§]	A	R	R	75
2	R	A	A	A	25
3	R	A	A	A	25
4	R	R	R	A	75
5	A	A	A	R	25
6	A	A	A	A	0
7	R	R	A	A	50

[†]Decision made at the 0.05 level of significance.

[§]A ≡ Accept the null hypothesis; R ≡ Reject the null hypothesis.

The remaining decision points, four in number, all contained more than two options. For this reason, a multiple range statistic was selected to allow the assessment of all possible comparisons between the options at each decision point. The results of these comparisons are presented in the table included as Appendix E to this report. Also included in this table is an analysis of variance for the options of each decision point. The F-ratio is used here as an overall test of the null hypothesis ($O_1 = O_2 = \ldots = O_k$) prior to probing the nature of the differences between the treatment means.

Shown in Table 13 is the accept-reject decision pattern for the DAIS decision points studied which contained more than two options. Fifteen of the 28 comparisons shown in this table would be accepted as representing real differences in the human resource components involved.

TABLE 13. ACCEPT-REJECT DECISION FOR THE NULL HYPOTHESIS† RESULTING FROM ANALYSIS OF VARIANCE OF THE HUMAN RESOURCE COMPONENTS AND DECISION POINTS SHOWN TOGETHER WITH THE PER CENT OF REJECTION OF THE NULL HYPOTHESIS FOR EACH HUMAN RESOURCE COMPONENT

HRC	Decision Points 2 (A,B,C,D)	4 (A,B,C)	5 (A,B,C)	6 (A,B,C,D,E,F)	Per Cent Rejection
1	R§	R	R	R	100
2	A	A	A	A	0
3	A	R	R	R	75
4	A	R	R	R	75
5	R	R	A	A	50
6	A	R	A	A	25
7	A	R	R	A	50

†Decision made at 0.05 level of significance.

§A ≡ Accept the null hypothesis; R ≡ Reject the null hypothesis.

In an attempt to seek insights into underlying relationships existing among the variables studied, correlation matrices for each of the human resource components against items of background information were computed. The tables in which the correlation matrices are shown in abbreviated form are contained in Appendix F. For ease of reading the table, a value is entered only for those variables achieving a correlation significant at the 0.05 level or better. This presentation makes is readily apparent that of a possible 1176 correlations, only 77 achieved significance.

DISCUSSION

The purpose of this study was to develop, apply, and evaluate the feasibility of a procedure for measuring the effects of technology on human resources. Interest was centered on development of a tool for use by system designers and manpower planners which would permit the specification, in advance of system development, of the effects of a technological innovation on the human resources required to interact with the technology in operation and maintenance of the system.

Three classes of data have been included in the study: First, seven human resource components selected to demonstrate the feasibility of associating human resource components with hardware decision options; second, the hardware decision options at eight decision points in the conceptualized digital avionics information system selected by representatives of the Air Force; and third, selected background and experience information on the technicians who serve as the source of the data.

The data collected have been analyzed through tests of the null hypothesis involving analysis of variance and t-tests, through multiple range test procedures to study patterns of differences, and through correlation techniques investigating relationships with selected background items.

For the seven human resource components selected for feasibility study, the survey results indicate that four of the components, i.e., worker preference, skill level required, difficulty level of task, and time required to maintain or troubleshoot were significantly impacted in half or more of the decision point/option alternatives sampled. Further, the options available at three of the decision points studied appeared to have the heaviest impact on the human resource components under investigation. These decision points impacting on four or more of the human resource components were: the choice of single or multiple multiplex data buses for the system; the commonality of LRU processors; and the type of software structure. Table 14 shows the combined t-test and F-ratio accept-reject matrix for the seven HRCs and eight decision points.

TABLE 14. COMPLETE ACCEPT-REJECT MATRIX FOR THE SEVEN HUMAN RESOURCE COMPONENTS AND THE EIGHT DECISION POINTS SURVEYED IN THE DAIS-DODT SURVEY

HRC	Decision Points †								Per cent Rejection
	1	2	3	4	5	6	7	8	
1	R	R	A	R	R	R	R	R	88
2	R	A	A	A	A	A	A	A	12
3	R	A	A	R	R	R	A	A	50
4	R	A	R	R	R	R	R	A	75
5	A	R	A	R	A	A	A	R	38
6	A	A	A	R	A	A	A	A	12
7	R	A	R	R	A	R	A	A	50

† Decision Points 1, 3, 7 and 8 compared by means of t-tests; decision points 2, 4, 5, and 6, by F-ratios.

Reflected below for the four HRCs most heavily impacted are the design options producing the impact. Included in parenthesis is the number of the decision point and the letter designation of the option.

Worker Preference:

Single multiplex data bus (MDB) (1A)

Electro/optical bus (2C)

Common peripheral processors (4C)

Modular software structure (5A)

Core memory in CPU (6A)

RTU serving only one subsystem (7A)

Modular signal modification equipment (8B)

Lower Skill Levels:

Single MDB (1A)

Common peripheral processors (4C)

Modular software structure (5A)

Tape memory (6D)

Least Difficult Task Options:

- Single MDB (1A)
- Single central processor (3A)
- Common peripheral processors (4C)
- Modular software (5A)
- Either core or tape memory (6A) (6D)
- RTU serving one subsystem (7A)

Least Maintenance Time Required for:

- Single MDB (1A)
- Single central processor (3A)
- Common peripheral processors (4C)
- Modular software (5A)

In addition to the human factor considerations, it is interesting to note the engineering implications of these choices as well. For example, consider the choices related to the memory type shown in Figure 1. As noted earlier, in discussing the four HRCs (worker preference, lower skill levels, least difficult task, and least maintenance time), there appeared to be a significant HRC impact in considering either tape or core memory. This tends to indicate that there is a direct relationship between the degree of engineering sophistication and the level of demand on the human factors elements, i.e., as the system becomes more complex so does the impact on human factors. From an engineering standpoint, it may be more convenient to utilize some other memory such as disc or semiconductor because of packaging, power requirements, etc., whereas from a human factors standpoint, the logical choice would be core or tape. Herein lies the contradiction between the engineering choice and the choice dictated by consideration of the human factors elements. However, without a procedure to evaluate such a tradeoff, the impact of human factors cannot be considered in the design phase of the system since the design engineer would have the total responsibility for the design choice. It must be pointed out, however, that consideration of human factors has in effect long-term engineering implications in that once a system is designed, it must be maintained and kept in an operational status. Therefore, initially there may appear to be a contradiction between engineering implications and human factors, but in effect the two approaches are compatible.

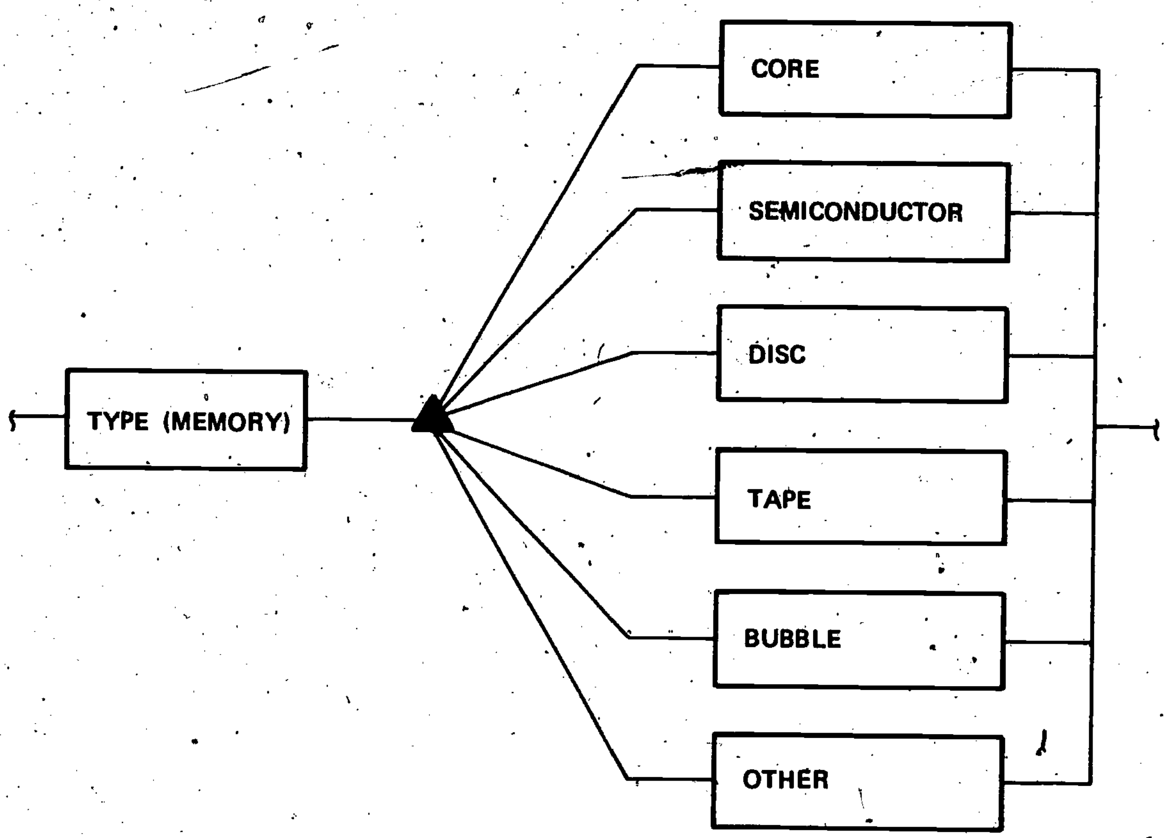

Figure 1. Various Types of Memories to be Considered in Digital Avionics Information Systems.

Using a segment of the DAIS-DODT as an example of assignment of derived human resource component values at the decision point options, an illustration of the decision trades possible and of the utility of the tool to system designers and manpower planners can be provided. In Figure 2, different paths are outlined through a segment of the DODT. The paths are held stable except for progress through three of the decision points studied.

It is possible to progress through the design tree with a goal of minimizing the impact on the human resource components (HRC) associated with each point. For example, following this philosophy for three human resource components (skill levels required, difficulty of maintenance or troubleshooting, and time required to maintain or troubleshoot) would result in following the path coded "1" through the tree. The total HRC Impact Score for this path is 33.3. If the worst case had been observed at each decision point for each of the 3 HRCs then the attained score would be 90. Next consider the path marked "2". This path depicts a system where at all decision points the options representing advanced technology are selected. The HRC Impact Score in this instance is 53.2. Thus the separate design philosophies through this segment of the DAIS-DODT result in scores of 33.3 and 53.2. Both of these compare against the worst case score of 90 as well as against each other. Thus, the value of a trade study at these points weighting available or obtainable human resources against technological requirements of a proposal system can be defined and accomplished by a system designer or other planners concerned with Air Force human resources. In these examples, the system segment could be designed to conserve any one or all of the three human resource components.

The results obtained from the correlational relationships between the design options and the items of background information surveyed are disappointing on the basis of numbers of significant correlations obtained. This phase of the analysis must be regarded as producing negative results. One possible insight resulting from inspection of these data is the suggestion that a changing relationship in worker response to different technological solutions on the basis of increases in age and experience might be operating. As an example, the single multiple data bus, significantly favored by the overall group of respondents, is viewed by the older

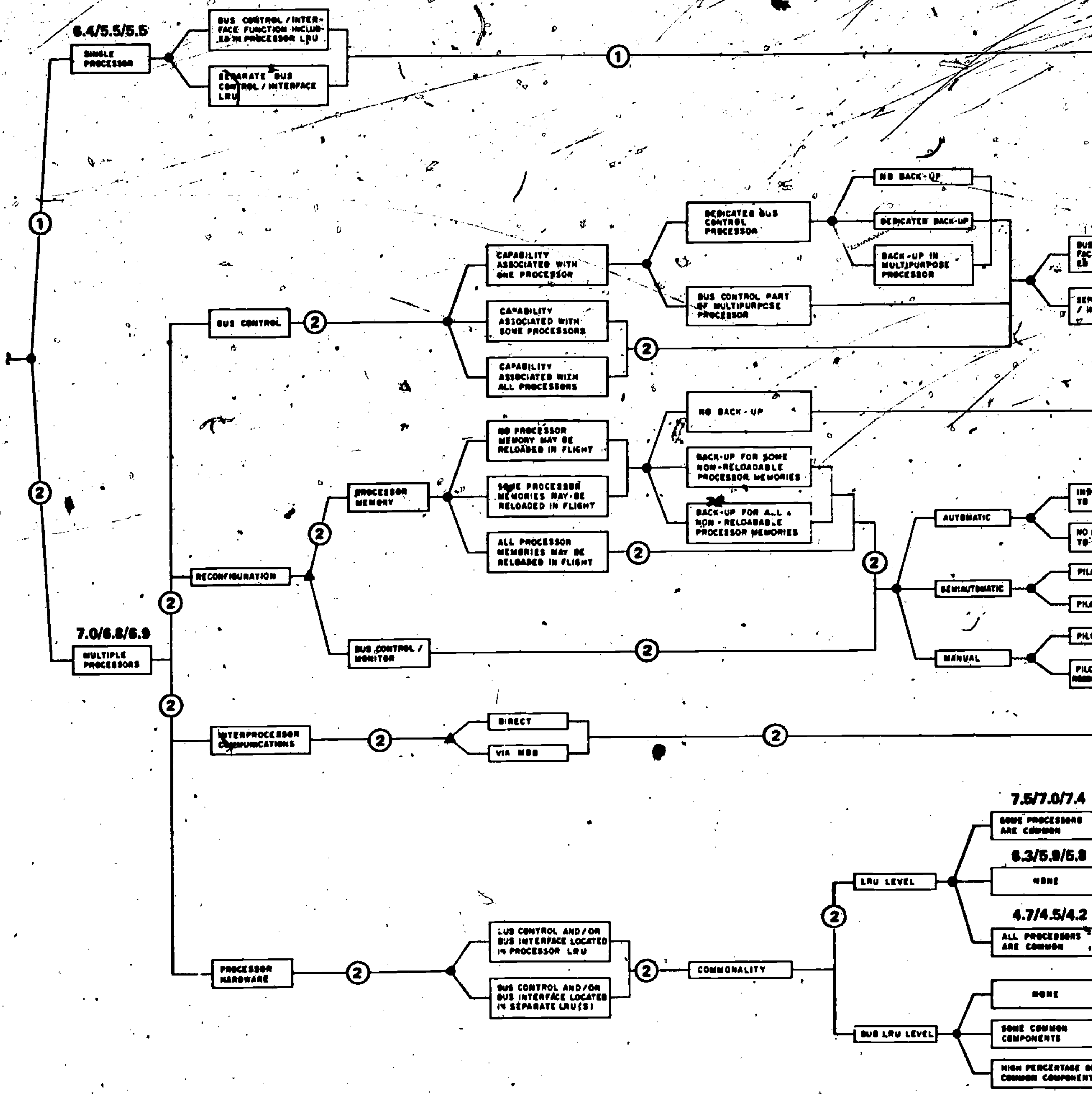

Figure 2. Segment of the Design C
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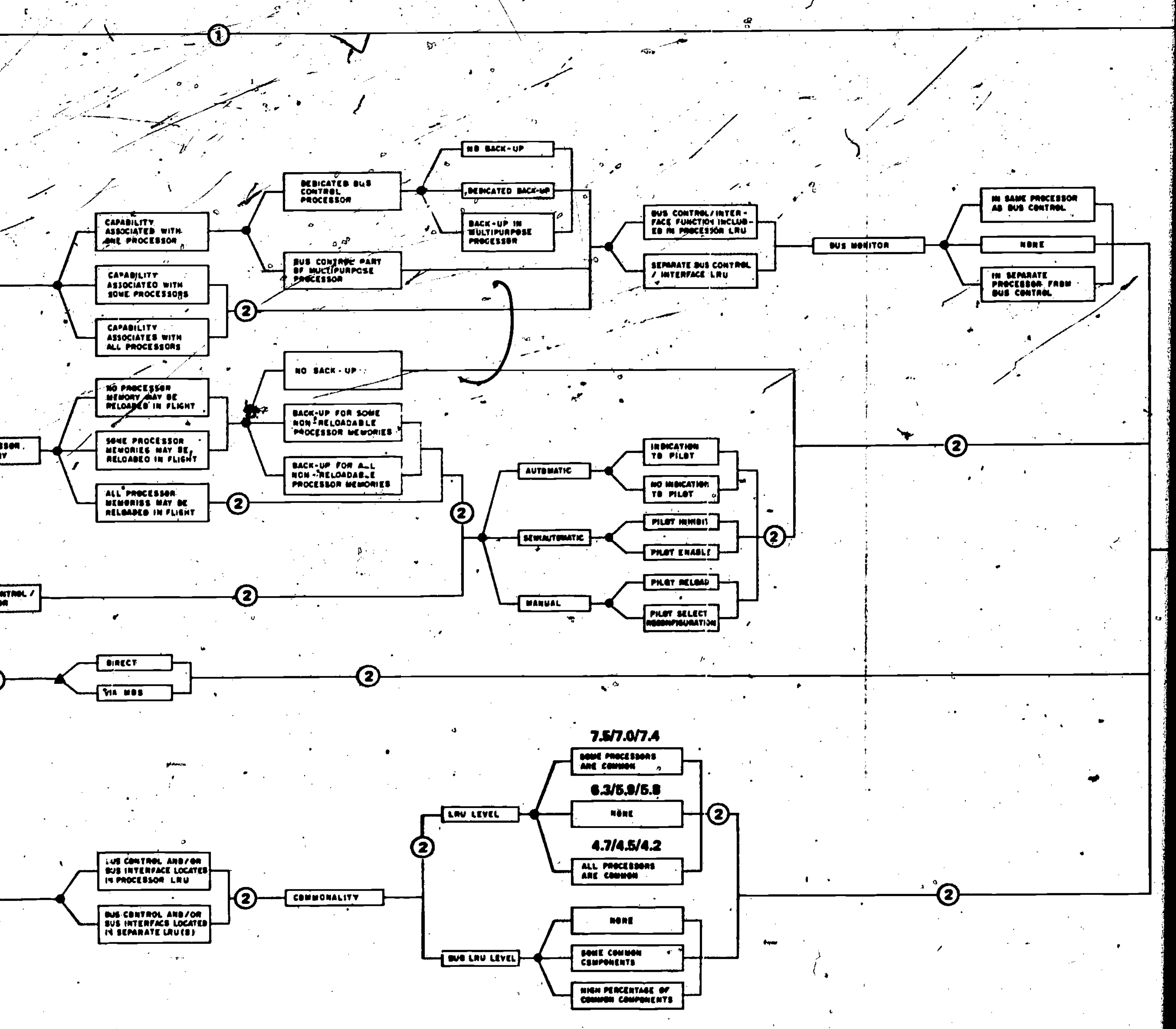
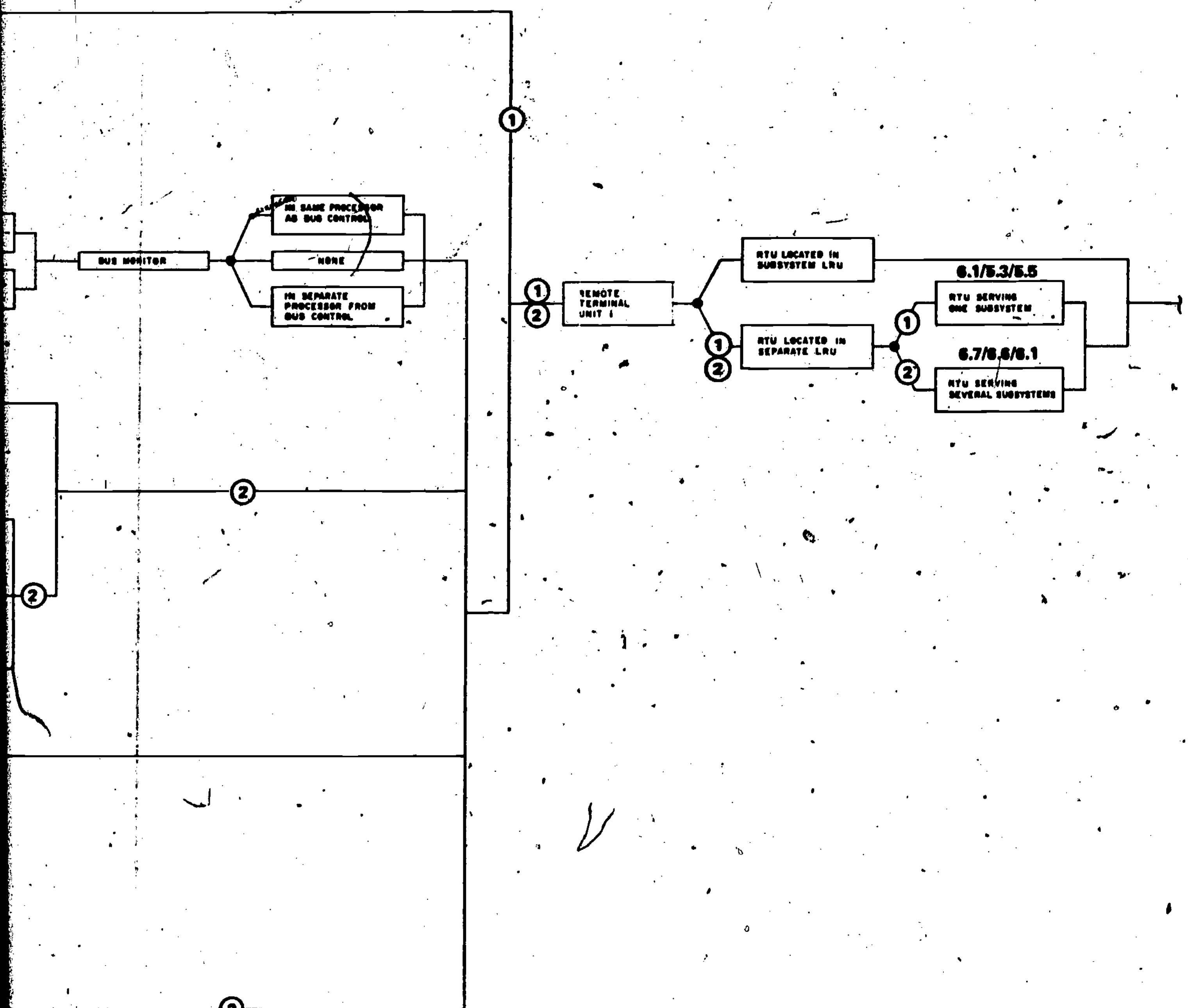


Figure 2. Segment of the Design Option Decision Tree Used to Demonstrate Decision Trades and Utility of Format.



cision Tree Used to
Utility of Format.

respondents as being more difficult to maintain and troubleshoot, to require more training, and to have maintenance and troubleshooting activities more adversely affected by extremes in the environment. However, additional supportive evidence would be necessary to establish an acceptable level of confidence in such a statement.

Unfortunately, the age distribution of the survey respondents was not under experimental control and, as reflected in Table 2, was heavily skewed in the direction of the younger ages. Projections of the age composition of the maintenance force in the time-frame for which an incoming system would be in the operational inventory and systematic selection of a sample representative of this composition would permit more accurate specification of technology impact on human resources of specific innovations and would provide a meaningful tool for engineering design and personnel action decisions in the early conceptual stages of system design.

CONCLUSIONS

The primary goal of this study effort was to develop techniques for determining and defining the components of new technology and for measuring the effects of that technology on the Air Force human resources required to interact with it. The intended purpose of such a technique is for prediction, at a very early time, of changes in technical manpower requirements from the perspective of changing technology.

The existing literature supported the use of a normative technique for forecasting and assessing technology. A normative approach known as a Design Option Decision Tree (DODT) was selected as the vehicle for locating technology within a proposed system.

The problem of quantizing the impact of projected technological innovations on human resources was not resolved through a review of the literature. No satisfactory technique was found to be in existence.

An adaptation of the summated rating technique was performed and a set of standardized questions developed to allow the collection of judgmental data which could be translated into quantized statements concerning predicted impact of technological advances on selected human resource components.

The human resource component values resulting from this process were assigned to decision alternatives at three decision points in a selected segment of the DAIS-DODT. This segment was used as an illustration of the utility of the procedure to system designers and personnel planners in the identification of human resource component trade studies required for certain desired design outcomes. The advantage of the proposed procedure lies in the fact that it would permit detailed identification of human resource component trade studies far in advance of hardware design decisions. Thus, the trade study results could serve as input data for influencing a hardware design decision.

The results obtained from application of this methodology are felt to demonstrate its feasibility and appear to encourage continued refinement of the procedure to result in the development of predictive equations which are no longer dependent upon the collection of judgmental data.

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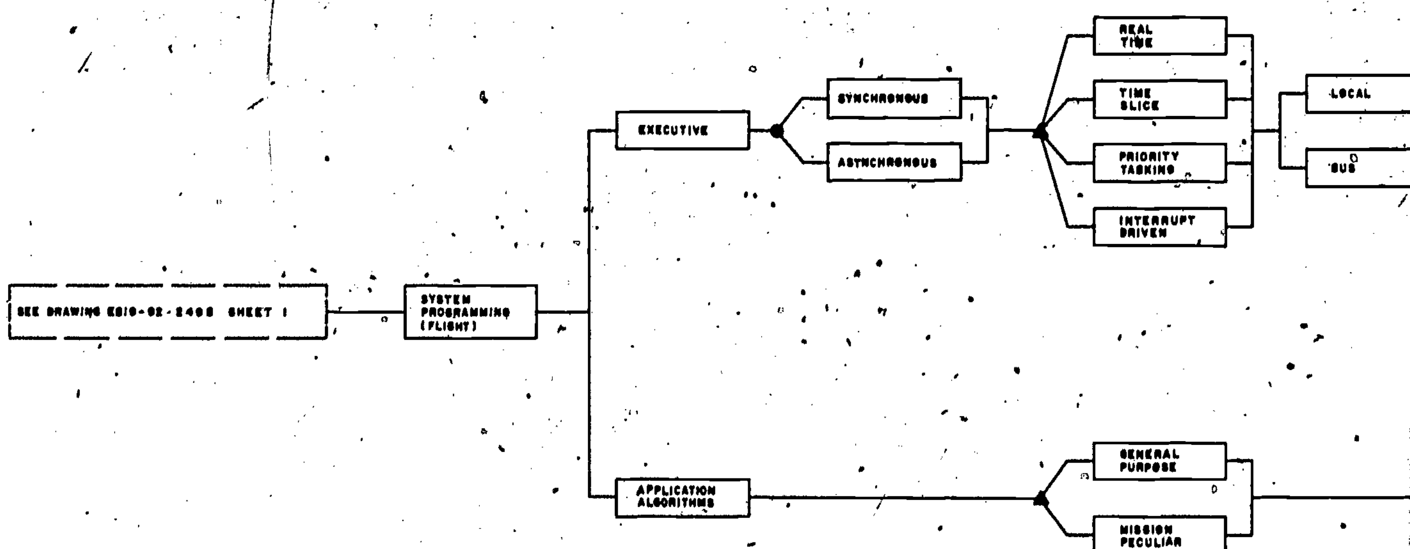
APPENDIX A

INFORMATION PROCESSING

DESIGN OPTION DECISION TREE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EXECUTIVE
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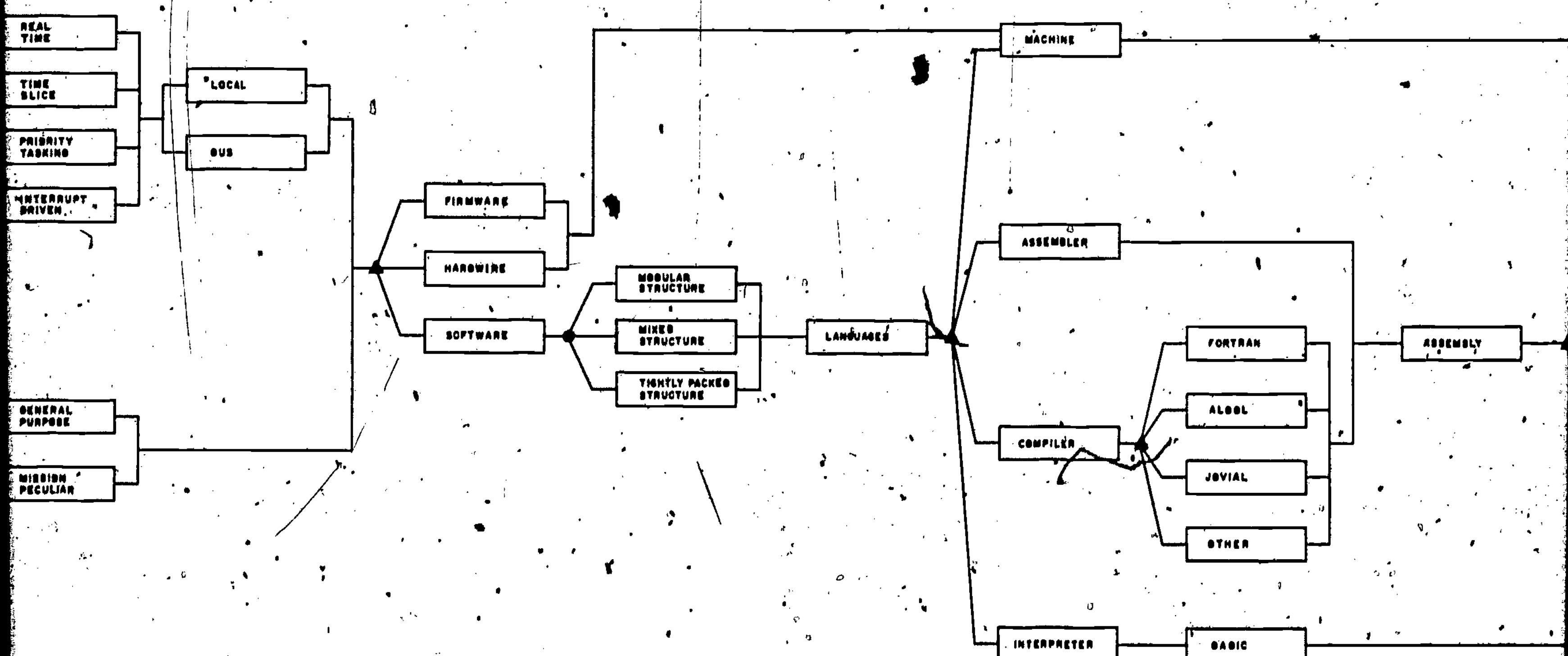
GENERAL PURPOSE
MISSION PECULIAR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HARDWIRE
SOFTWARE
MODULAR STRUCTURE
MIXED STRUCTURE
TIGHTLY PACKED STRUCTURE
LANGUAGES
MACHINE
ASSEMBLER
COMPILER
INTERPRETER
FORTRAN
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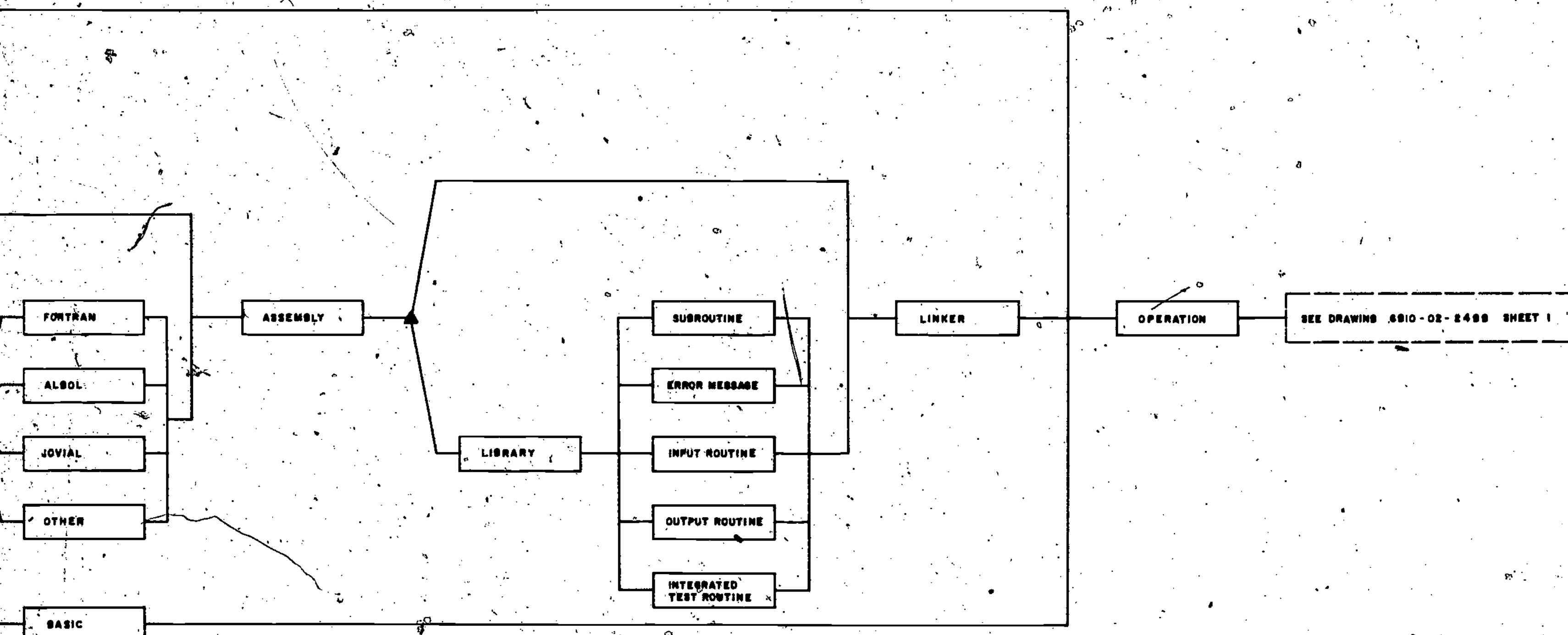
ASSEMBLY

6810-02-2499


FORTRAN
ALGOL
JOVIAL
OTHER
BASIC
ASSEMBLY
LIBRARY
SUBROUTINE
ERROR MESSAGE
INPUT ROUTINE
OUTPUT ROUTINE
INTEGRATED TEST ROUTINE
LINKER
OPERATION
SEE DRAWING 6910-02-2499 SHEET 1

6910-02-2499

DECISION TREE
INFORMATION PROCESSING
(SYSTEM PROGRAMMING)

T. WALSH 10-6-74

14590 6610-02-2499

6610-02-2499

APPENDIX B

TAC/AFHRL DESIGN OPTION DECISION

TREE MAINTENANCE SURVEY BOOKLET

NOTE: The survey booklet was set up with the schematic on the left side and the questions on the right side, so that the respondent would answer questions with schematic present. For purposes of cost savings only one example of the questions is shown. All schematics are provided.

TAC/AFHRL DESIGN OPTION DECISION

TREE MAINTENANCE SURVEY

MYRTLE BEACH AFB, SC

Digital Avionics
Information Processing Systems
(AUGUST 1974)

DESIGN OPTION DECISION TREE
MAINTENANCE SURVEY QUESTIONNAIRE

1. How would you feel about working on each choice?

Strongly Opposed	One is as Good as Another	Strongly Favor

2. How much would a written procedural manual help with maintaining or troubleshooting each choice?

Strongly Hinder	Neither Hinder Nor Help	Strongly Help

3. Indicate the amount of skill needed to maintain or troubleshoot each choice.

Very Little	Average	Most

4. How difficult would be the task of maintaining or troubleshooting each choice?

Very Easy	Average	Very Difficult

5. How much training is necessary to maintain or troubleshoot each choice?

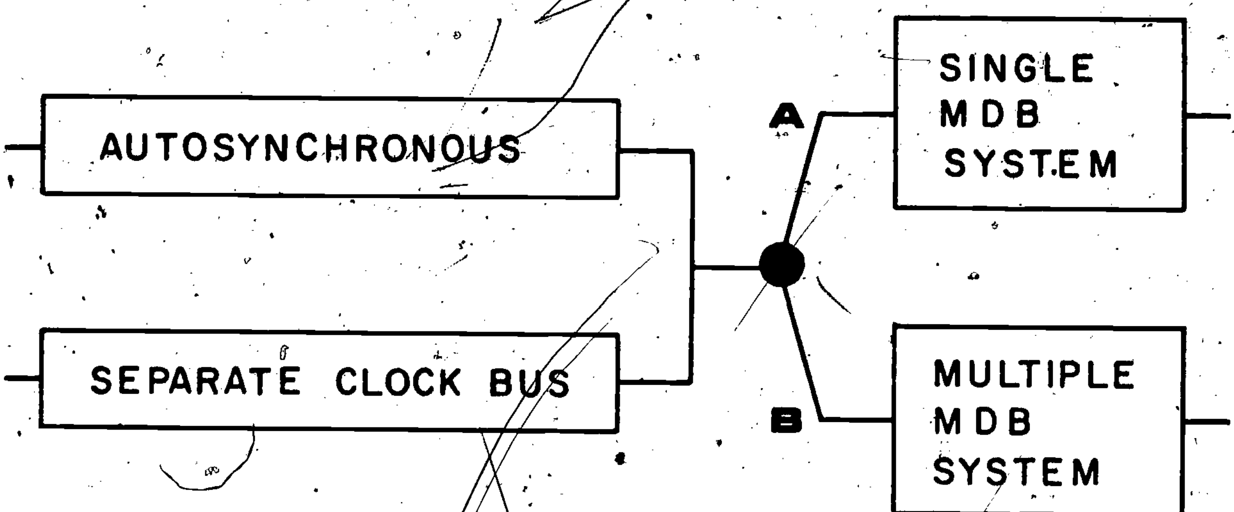
Very Little	Average Amount	Great Amount

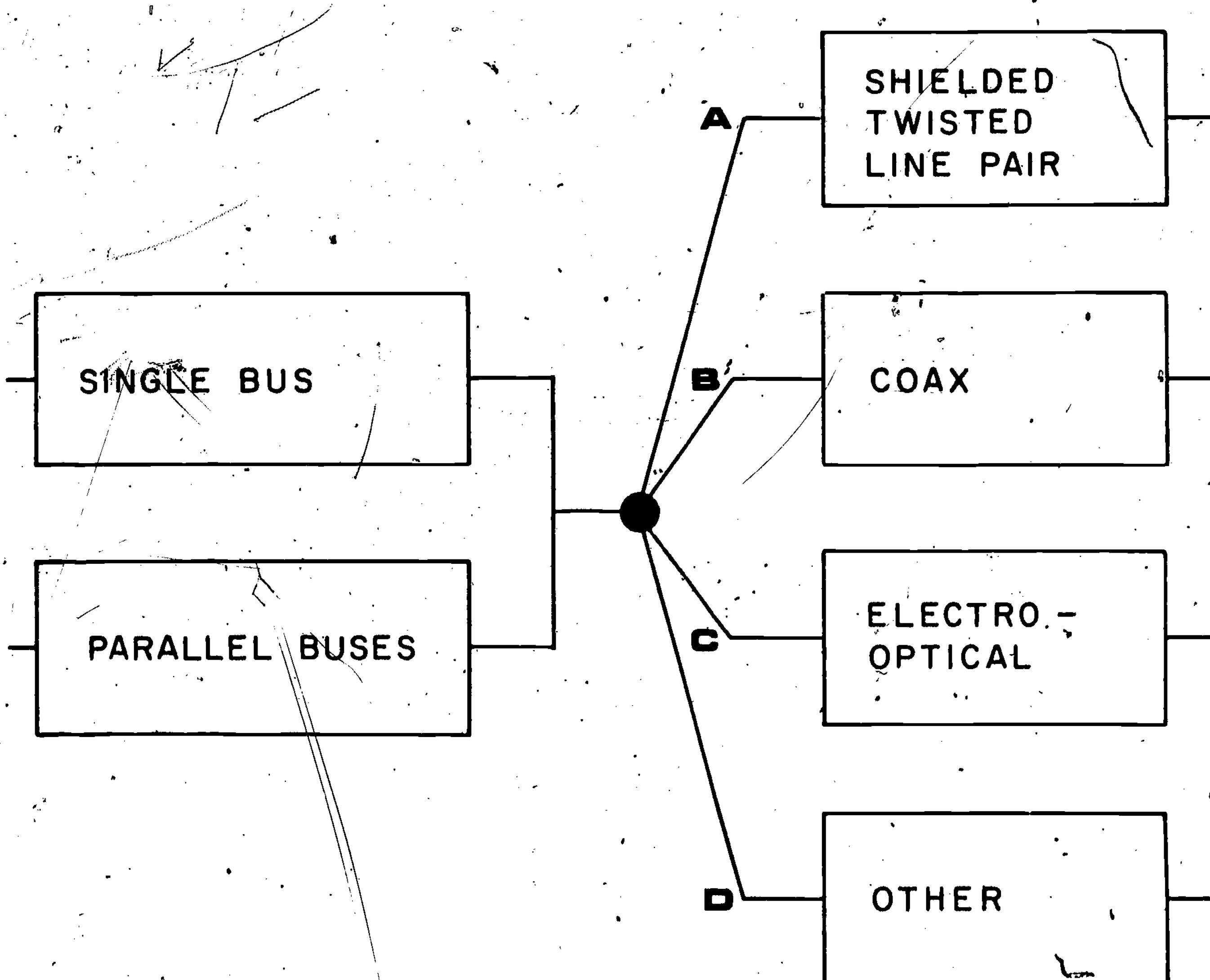
6. How difficult would it be to maintain or troubleshoot each choice in extreme environments?

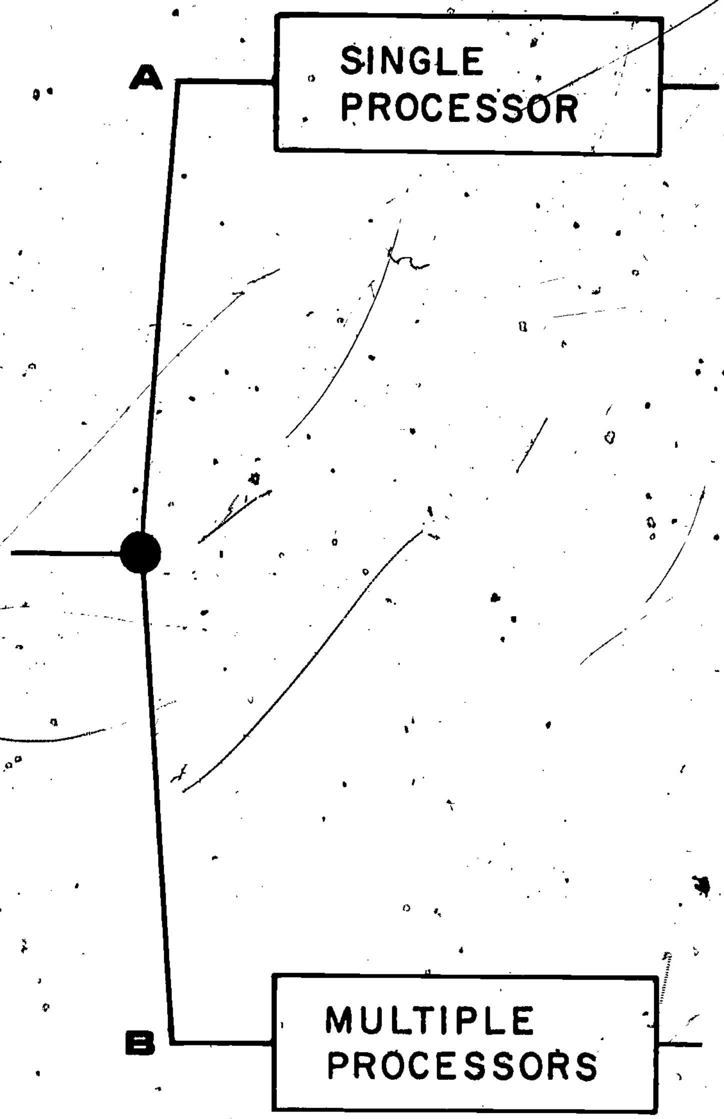
Little Difficulty	Average Difficulty	Strong Difficulty

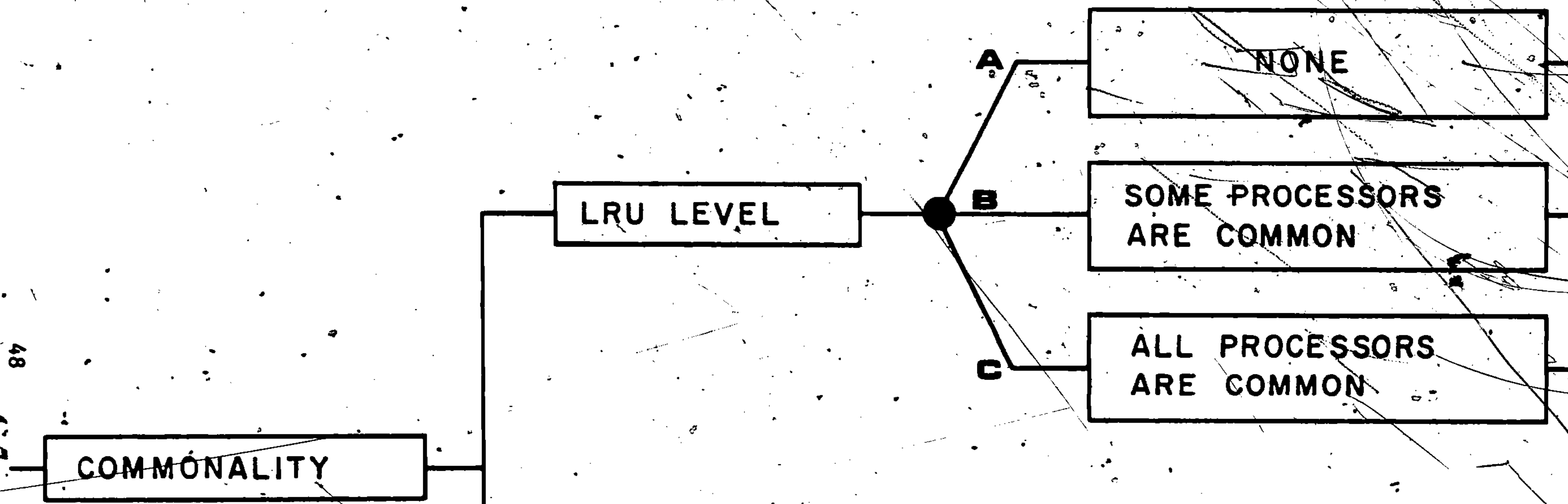
7. How time consuming do you feel maintaining or troubleshooting each choice would be?

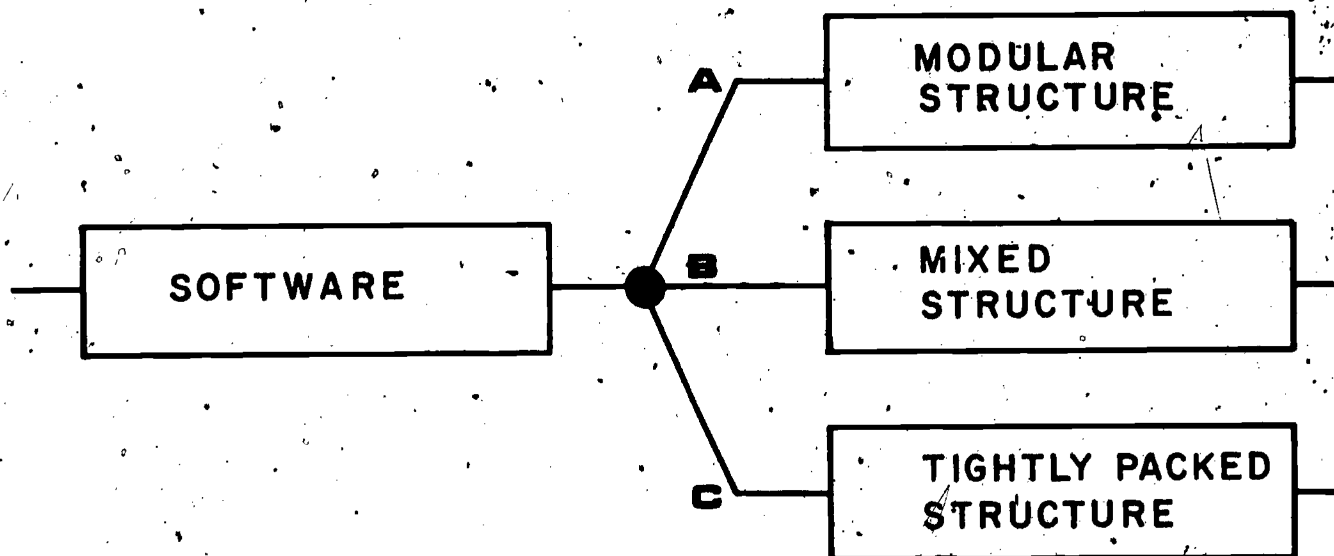
Very Little	Average	Great Amount

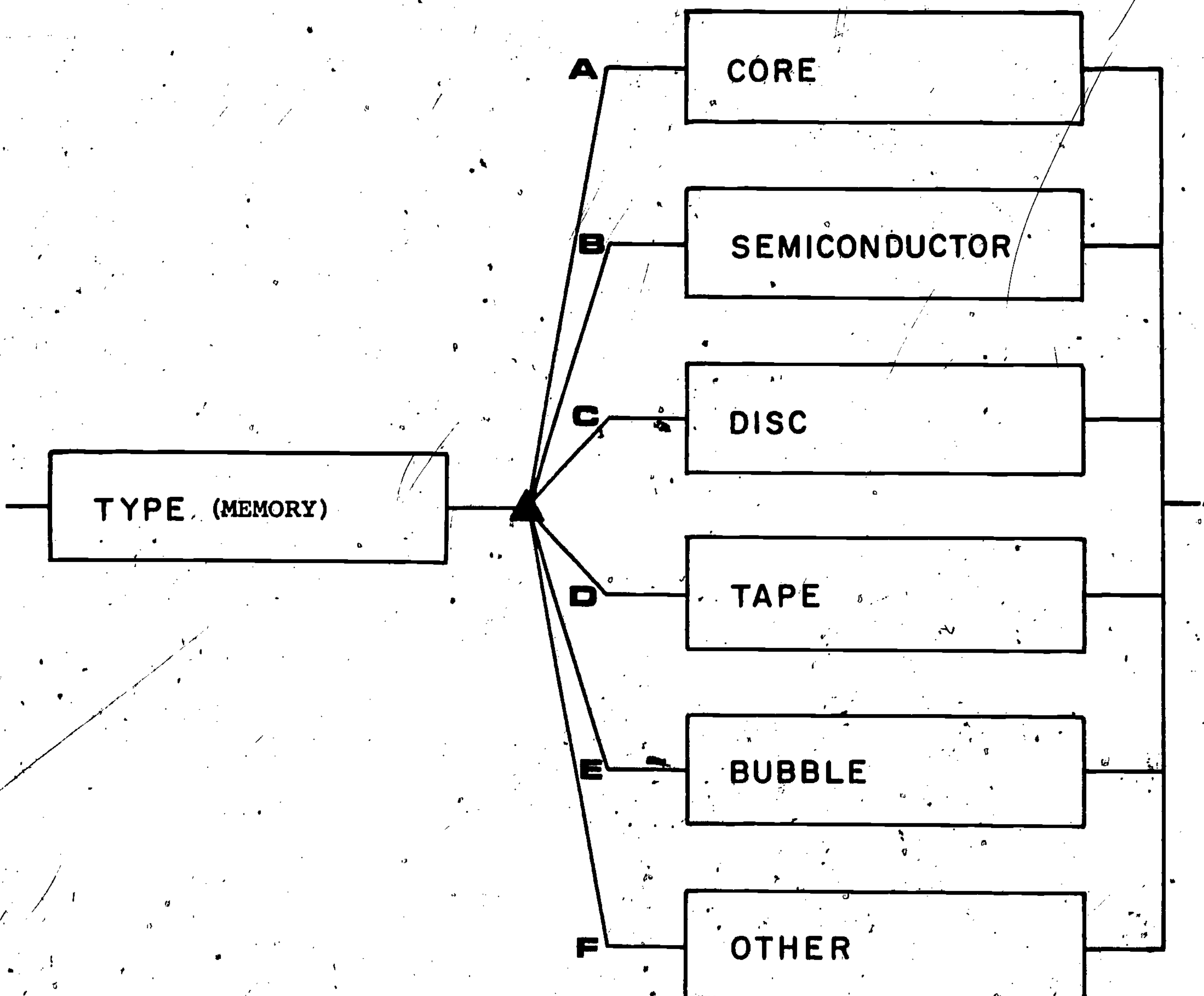

AUTOSYNCHRONOUS
SEPARATE CLOCK BUS
A
B
SINGLE MDB SYSTEM
MULTIPLE MDB SYSTEM

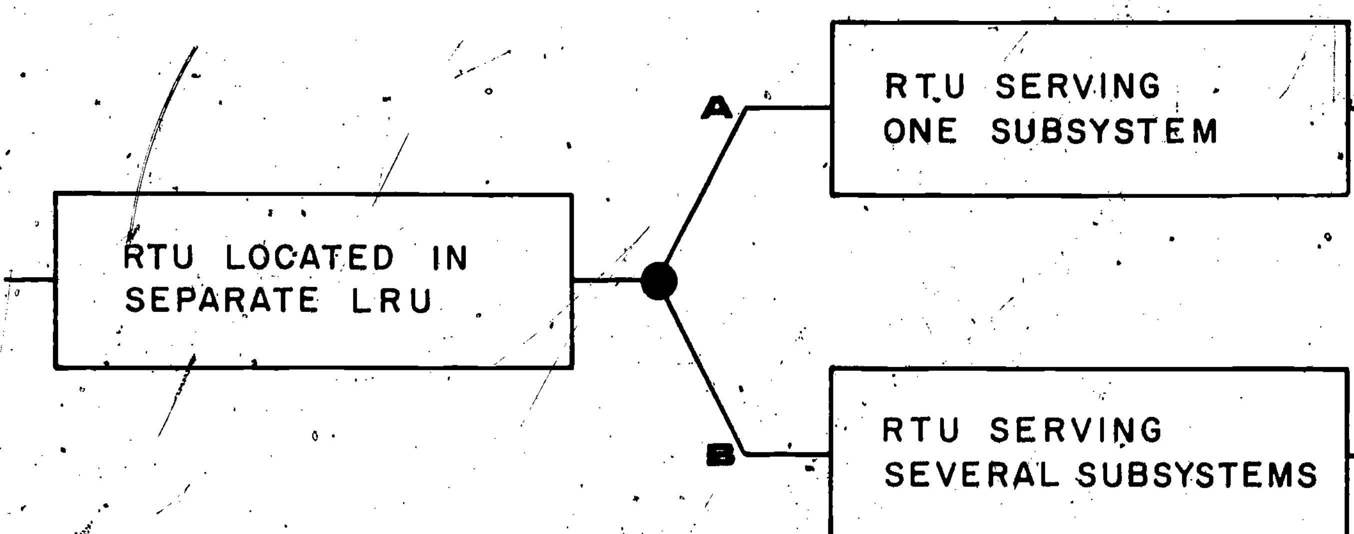

SINGLE BUS
PARALLEL BUSES
A
B
C
D
SHIELDED TWISTED LINE PAIR
COAX
ELECTRO.-OPTICAL
OTHER

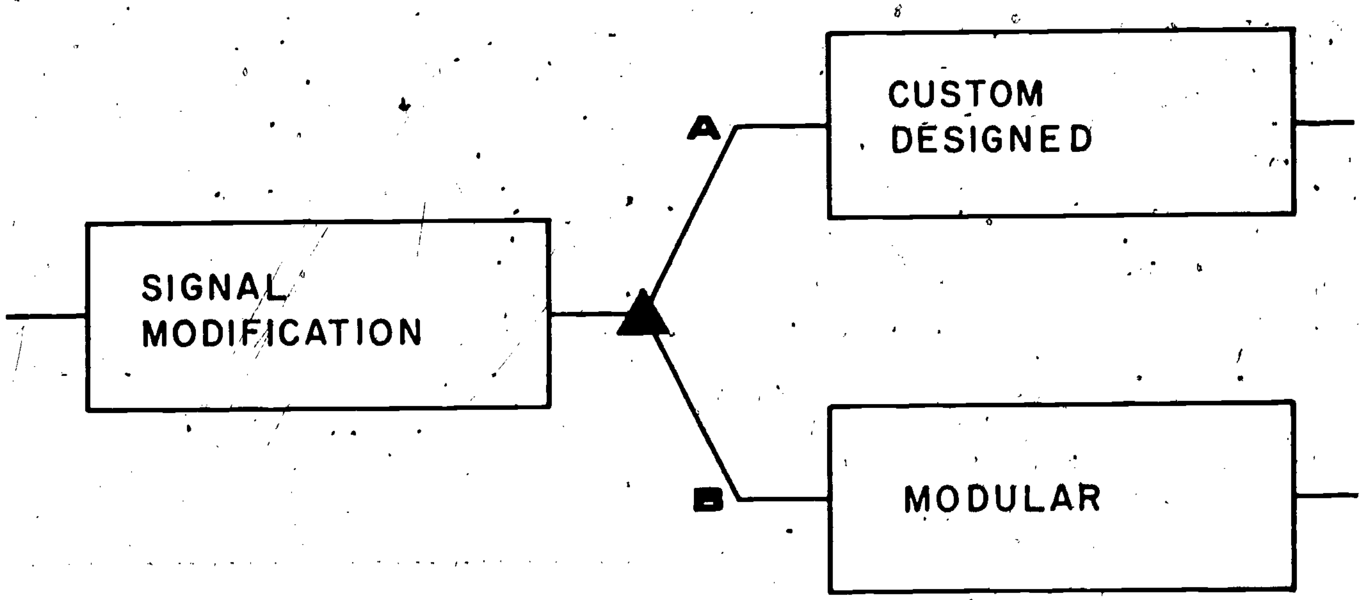

A
SINGLE
PROCESSOR
B
MULTIPLE
PROCESSORS


COMMONALITY
LRU LEVEL
A
B
C
NONE
SOME PROCESSORS ARE COMMON
ALL PROCESSORS ARE COMMON


SOFTWARE
A
B
C
MODULAR STRUCTURE
MIXED STRUCTURE
TIGHTLY PACKED STRUCTURE


TYPE (MEMORY)
A
CORE
B
SEMICONDUCTOR
C
DISC
D
TAPE
E
BUBBLE
F
OTHER


RTU LOCATED IN
SEPARATE LRU
A
RTU SERVING
ONE SUBSYSTEM
B
RTU SERVING
SEVERAL SUBSYSTEMS


SIGNAL MODIFICATION
A
CUSTOM DESIGNED
B
MODULAR

DESIGN OPTION DECISION TREE MAINTENANCE SURVEY

PERSONNEL BACKGROUND INFORMATION QUESTIONNAIRE

1. Name ______________________ 2. Rank ______________

3. Organization ______________________

4. Age ______________

5. Duty AFSC ______________

6. Job Title ______________________

7. Number of calendar months in present assignment ______________

8. Total years of duty related experience ______________

9. Types of aircraft worked on and system worked on in each aircraft.

10. Total number of years in military service ______________

11. List technical service schools attended

12. In what specialty do you feel best qualified? ______________

13. What is highest school grade completed? ______________

14. How many of the past five years are applicable to present duty assignment? ______________________

APPENDIX C

DATA RECORDING FORM

SUBJECT:

QUESTIONS	AUTOSYNCHRONOUS / SEPARATE CLOCK BUS: SINGLE MDB SYS	MULTIPLE MDB SYS	SINGLE BUS / PARALLEL BUS: SHIELDED TWISTED LINE PAIR	COAX	ELECTRO-OPTICAL	OTHER	SINGLE PROCESSOR	MULTIPLE PROCESSOR	COMMONALITY - LRU LEVEL: NONE	SOME PROCESSORS ARE COMMON	ALL PROCESSORS ARE COMMON	SOFTWARE: MODULAR STRUCTURE	MIXED STRUCTURE	TIGHTLY PACKED STRUCTURE	MEMORY TYPE: CORE	SEMICONDUCTOR	DISC	TAPE	BUBBLE	OTHER	RTU LOCATED IN SEPARATE LRU: RTU SERVING ONE SUBSYSTEM	RTU SERVING SEVERAL SUBSYSTEMS	SIGNAL MODIFICATION: CUSTOM DESIGNED	MODULAR
	1		2				3		4			5			6						7		8	
	A	B	A	B	C	D	A	B	A	B	C	A	B	C	A	B	C	D	E	F	A	B	A	B
1. How would you feel about working on each choice? (Strongly Opposed — One is as Good as Another — Strongly Favor)																								
2. How much would a written procedural manual help with maintaining or troubleshooting each choice? (Strongly Hinder — Neither Hinder Nor Help — Strongly Help)																								
3. Indicate the amount of skill needed to maintain or troubleshoot each choice. (Very Little — Average — Most)																								
4. How difficult would be the task of maintaining or troubleshooting each choice? (Very Easy — Average — Very Difficult)																								
5. How much training is necessary to maintain or troubleshoot each choice? (Very Little — Average Amount — Great Amount)																								
6. How difficult would it be to maintain or troubleshoot each choice in extreme environments? (Little Difficulty — Average Difficulty — Strong Difficulty)																								
7. How time consuming do you feel maintaining or troubleshooting each choice would be? (Very Little — Average — Great Amount)																								

APPENDIX D

INSTRUCTIONS TO INTERVIEWERS

OUTLINE

TOPICS TO BE DISCUSSED WITH SURVEY RESPONDENTS

Both the periods of availability of respondents and the numbers available at a given time are subject to variation. For this reason, rather than provide a verbatim script of instructions to respondents, an outline of the topics which should be covered is provided. It is important that respondents understand exactly the nature of the task being asked of them. For this reason, be certain that all questions are answered to the groups' satisfaction before proceeding.

Topics

1. Survey Introduction
   - A. Name of SRL interviewers
   - B. Identification of sponsor
   - C. Reason for being there
     — to collect data relating to digital avionics
   - D. Purpose for collecting data
     — to attach meaningful numbers to decision alternatives related to digital avionics
     — trying to develop a procedure which will permit Air Force system designers to take into consideration the effects of certain design decisions on maintenance and troubleshooting so that, for example, a system can be designed for ease of maintenance where possible.
   - E. Why Myrtle Beach AFB
     — A-7 experience (digital equipment). (Avionics Laboratory at WPAFB using A-7 avionics as base line for DAIS development)

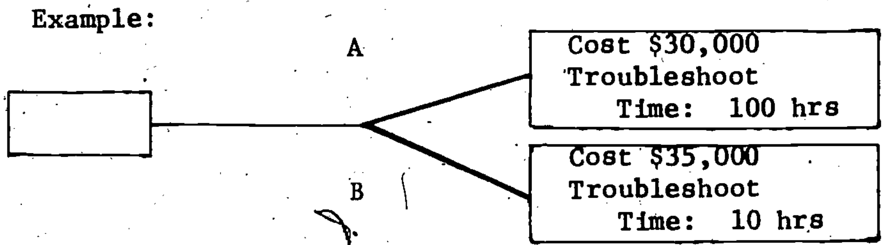
2. DODT (DAIS) Presentation and Explanation
   - A. Explain what the task is
   - B. Emphasize this is to be done only for 8 decision points <u>NOT</u> entire tree

3. Intended Use for Myrtle Beach AFB Survey Information

   A. Seeking to attach meaningful numbers to various decisions related to weapon system

   B. Trying to get information which will allow consideration of the human maintenance and operation problems of a system.

   Example:

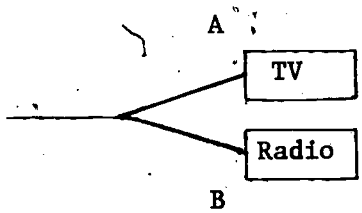


4. Procedure to be followed:

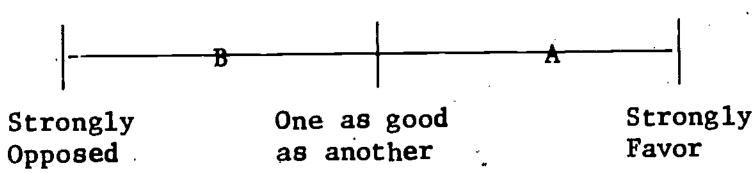
   A. Ask for any questions on what has been said

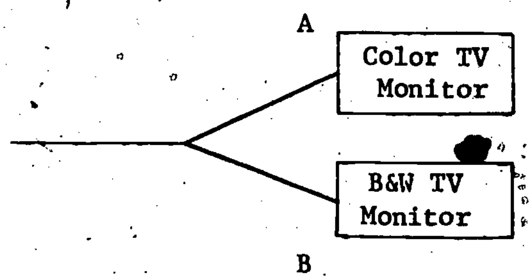
   B. Pass out survey

   C. Go over examples A and B Below

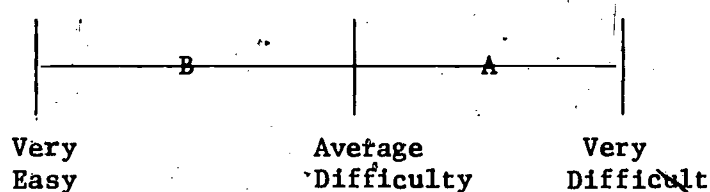


How would you feel about working on each





How difficult would be the task of minimizing each choice



D. Ask for questions on procedure to be followed.

E. Instruct technicians to proceed with the survey.

F. Be sure to indicate that questions may be asked at any point on the procedure to be followed.

APPENDIX E

SUMMARY TABLE OF ANALYSIS OF VARIANCE AND STUDENT-NEWMAN-KEULS TEST OF DIFFERENCES BETWEEN MEANS FOR HUMAN RESOURCE COMPONENTS AND DECISION POINTS INDICATED

TABLE E-1. SUMMARY TABLE OF ANALYSIS OF VARIANCE AND STUDENT-NEWMAN-KEULS TEST OF DIFFERENCES BETWEEN MEANS FOR HUMAN RESOURCE COMPONENTS AND DECISION POINTS INDICATED

Human Resource Component 1

Decision Point 2

ANOVA

Source	SS	df	MS	F
Options	86.28	2	43.14	6.50**
Exp. Error	557.31	84	6.63	
Total	643.59	86		

S-N-K

Order	1	2	3
Option	B	A	C
B	--	21	69**
A		--	48*
C			--

Decision Point 4

ANOVA

Source	SS	df	MS	F
Options	273.49	2	136.74	23.13**
Exp. Error	514.30	87	5.91	
Total	787.79	89		

S-N-K

Order	1	2	3
Option	A	B	C
A	--	49*	127**
B		--	78**
C			--

Decision Point 5

ANOVA

Source	SS	df	MS	F
Options	83.69	2	41.86	6.16**
Exp. Error	631.94	93	6.80	
Total	715.63	95		

S-N-K

Order	1	2	3
Option	C	B	A
C	--	32	73**
B		--	41
A			--

Decision Point 6

ANOVA

Source	SS	df	MS	F
Option	112.51	4	28.13	3.66**
Exp. Error	960.88	125	7.69	
Total	1073.99	129		

S-N-K

Order	1	2	3	4	5
Option	E	D	C	B	A
E	--	8	11	25	68**
D		--	3	17	60*
C			--	14	57*
B				--	43*
A					--

Human Resource Component 2

Decision Point 2

ANOVA

Source	SS	df	MS	F
Options	10.09	2	5.05	1.44
Exp. Error	293.72	84	3.50	
Total	303.82	86		

S-N-K

Order	1	2	3
Option	A	B	C
A	--	5	23
B		--	18
C			--

Decision Point 4

ANOVA

Source	SS	df	MS	F
Option	0.42	2	0.21	
Exp. Error	234.47	87	2.70	
Total	234.89	89		

S-N-K

Order	1	2	3
Option	A	B.	C
A	--	2	5
B		--	3
C			--

Decision Point 5

ANOVA

Source	SS	df	MS	F
Option	0.93	2	0.46	
Exp. Error	229.35	90	2.55	
Total	230.28	92		

S-N-K

Order	1	2	3
Option	A	B	C
A	--	6	7
B		--	1
C			--

Decision Point 6

ANOVA

Source	SS	df	MS	F
Option	3.89	4	0.97	
Exp. Error	3537.28	120	29.48	
Total	3541.17	124		

S-N-K

Order	1	2	3	4	5
Option	D	C	B	A	E
D	--	3	4	7	13
C		--	1	4	10
B			--	3	9
A				--	6
E					--

Human Resource Component 3

Decision Point 2

ANOVA

Source	SS	df	MS	F
Option	15.29	2	7.64	1.22
Exp. Error	546.53	87	6.78	
Total	561.82	89		

S-N-K

Order	1	2	3
Option	B	A	C
B	--	4	28
A		--	24
C			--

Decision Point 4

ANOVA

Source	SS	df	MS	F
Option	120.87	2	60.43	8.77**
Exp. Error	599.63	87	6.89	
Total	720.50	89		

S-N-K

Order	1	2	3
Option	C	B	A
C	--	47*	85**
B		--	38
A			--

Decision Point 5

ANOVA

Source	SS	df	MS	F
Option	40.40	2	20.20	3.89*
Exp. Error	482.56	93	5.19	
Total	522.96	95		

S-N-K

Order	1	2	3
Option	A	B	C
A	--	17	50*
B		--	33
C			--

Decision Point 6

ANOVA

Source	SS	df	MS	F
Option	98.38	4	24.60	5.03**
Exp. Error	538.35	110	4.89	
Total	636.73	114		

S-N-K

Order	1	2	3	4	5
Option	D	C	A	B	E
D		18	24	27	65**
C		--	6	9	47*
A			--	3	41*
B				--	38*
E					--

82

Human Resource Component 4

Decision Point 2

ANOVA

Source	SS	df	MS	F
Option	23.49	2	11.74	1.82
Exp. Error	561.50	87	6.45	
Total	584.99	89		

S-N-K

Order	1	2	3
Option	A	B	C
A	--	13	37
B		--	24
C			--

Decision Point 4

ANOVA

Source	SS	df	MS	F
Option	81.67	2	40.84	7.30**
Exp. Error	486.73	87	5.59	
Total	568.40	89		

S-N-K

Order	1	2	3
Option	C	B	A
C	--	35	70**
B		--	35
A			--

83

Decision Point 5

ANOVA

Source	SS	df	MS	F
Option	42.44	2	21.22	4.00*
Exp. Error	493.22	93	5.30	
Total	535.66	95		

S-N-K

Order	1	2	3
Option	A	B	C
A	--	23	52*
B		--	29
C			--

Decision Point 6

ANOVA

Source	SS	df	MS	F
Option	95.47	4	23.87	4.32**
Exp. Error	636.00	115	5.53	
Total	731.47	119		

S-N-K

Order	1	2	3	4	5
Option	D	A	C	B	E
D	--	2	4	20	57**
A		--	2	18	55**
C			--	16	53**
B				--	37*
E					--

Human Resource Component 5

Decision Point 2

ANOVA

Source	SS	df	MS	F
Option	68.64	2	34.32	5.31**
Exp. Error	523.68	81	6.47	
Total	592.32	83		

S-N-K

Order	1	2	3
Option	A	B	C
A	--	13	59**
B		--	46*
C			--

Decision Point 4

ANOVA

Source	SS	df	MS	F
Option	184.42	2	92.21	16.53**
Exp. Error	485.37	87	5.58	
Total	669.79	89		

S-N-K

Order	1	2	3
Option	C	B	A
C	--	58**	105**
B		--	47*
A			--

Decision Point 5

ANOVA

Source	SS	df	MS	F
Option	12.56	2	6.28	1.30
Exp. Error	448.06	93	4.82	
Total	460.62	95		

S-N-K

Order	1	2	3
Option	A	B	C
A	--	6	27
B		--	21
C			--

Decision Point 6

ANOVA

Source	SS	df	MS	F
Option	53.22	4	13.30	2.41
Exp. Error	634.75	115	5.52	
Total	687.97	119		

S-N-K

Order	1	2	3	4	5
Option	D	C	A	B	E
D	--	8	17	27	46*
C		--	9	19	38
A			--	10	29
B				--	19
E					--

Human Resource Component 6

Decision Point 2

ANOVA

Source	SS	df	MS	F
Option	6.00	2	3.00	
Exp. Error	545.32	81	6.73	
Total	551.32	83		

S-N-K

Order	1	2	3
Option	A	B	C
A	--	12	18
B		--	6
C			--

Decision Point 4

ANOVA

Source	SS	df	MS	F
Option	106.87	2	53.43	9.68**
Exp. Error	480.03	87	5.52	
Total	586.90	89		

S-N-K

Order	1	2	3
Option	C	B	A
C	--	43*	80**
B		--	37*
A			--

Decision Point 5

ANOVA

Source	SS	df	MS	F
Option	15.02	2	7.51	1.37
Exp. Error	510.81	93	5.49	
Total	525.83	95		

S-N-K

Order	1	2	3
Option	A	B	C
A	--	15	31
B		--	16
C			--

Decision Point 6

ANOVA

Source	SS	df	MS	F
Option	10.13	4	2.53	
Exp. Error	576.46	115	5.01	
Total	586.59	119		

S-N-K

Order	1	2	3	4	5
Option	A	C	D	B	E
A	--	3	4	6	20
C		--	1	3	17
D			--	2	16
B				--	14
E					--

Human Resource Component 7

Decision Point 2

ANOVA

Source	SS	df	MS	F
Option	2.00	2	1.00	
Exp. Error	555.29	81	6.86	
Total	557.29	83		

S-N-K

Order	1	2	3
Option	A	C	B
A	--	8	10
C		--	2
B			--

Decision Point 4

ANOVA

Source	SS	df	MS	F
Option	160.07	2	80.03	13.20**
Exp. Error	527.53	87	6.06	
Total	687.60	89		

S-N-K

Order	1	2	3
Option	C	B	A
C	--	49*	98**
B		--	49*
A			--

Decision Point 5

ANOVA

Source	SS	df	MS	F
Option	27.15	2	13.57	2.39
Exp. Error	528.34	93	5.68	
Total	555.49	95		

S-N-K

Order	1	2	3
Option	A	B	C
A	--	27	41
B		--	14
C			--

Decision Point 6

ANOVA

Source	SS	df	MS	F
Option	88.58	4	22.15	4.44*
Exp. Error	574.08	115	4.99	
Total	662.67	119		

S-N-K

Order	1	2	3	4	5
Option	D	C	A	B	E
D	--	11	18	31	60**
C		--	7	20	49*
A			--	13	42*
B				--	29
E					--

** Denotes Statistical Significance at the 0.01 level or better.

* Denotes Statistical Significance at the 0.05 level or better.

APPENDIX F

SIGNIFICANT CORRELATIONS EXISTING BETWEEN SPECIFIED DESIGN OPTIONS AND DESIGNATED BACKGROUND INFORMATION ITEM

TABLE F-1. SIGNIFICANT CORRELATIONS EXISTING BETWEEN SPECIFIED DESIGN OPTIONS AND ITEMS OF BACKGROUND INFORMATION INDICATED FOR THE HUMAN RESOURCE COMPONENT - WORK PREFERENCE, SAMPLE OF 32 MAINTENANCE TECHNICIANS, 354th AVIONICS SQUADRON, MYRTLE BEACH, SOUTH CAROLINA, AUGUST 1974

	Background Information						
	Rank	Age	Asgn	Xper	Yrs Svs	Yrs Sch	Last 5 Yrs Exp
1B	0.398	0.468		0.407			
4A							
4B			-0.374				
4C	0.357	0.582					0.355
5B						0.392	
6B							
6C	0.462			0.536			
6E		-0.437		-0.450	-0.416		
8A			-0.376				

TABLE F-2. SIGNIFICANT CORRELATIONS EXISTING BETWEEN SPECIFIED DESIGN OPTIONS AND ITEMS OF BACKGROUND INFORMATION INDICATED FOR THE HUMAN RESOURCE COMPONENT - WRITTEN PROCEDURES, SAMPLE OF 32 MAINTENANCE TECHNICIANS, 354th AVIONICS SQUADRON, MYRTLE BEACH, SOUTH CAROLINA, AUGUST 1974

	Background Information						
	Rank	Age	Asgn	Xper	Yrs Svs	Yrs Sch	Last 5 Yrs Exp
4C							
6A	0.460						
6B	0.486						0.411
6C	0.433						
8A			0.406				
8B					0.367		

TABLE F-3. SIGNIFICANT CORRELATIONS EXISTING BETWEEN SPECIFIED DESIGN OPTIONS AND ITEMS OF BACKGROUND INFORMATION INDICATED FOR THE HUMAN RESOURCE COMPONENT - <u>SKILL REQUIRED</u>, SAMPLE OF 32 MAINTENANCE TECHNICIANS, 354th AVIONICS SQUADRON, MYRTLE BEACH, SOUTH CAROLINA, AUGUST 1974

	Background Information						
	Rank	Age	Asgn	Xper	Yrs Svs	Yrs Sch	Last 5 Yrs Exp
1B				0.393			
2B			0.393				
3A				0.365			
4B			0.356				
6A					-0.501		
6B		-0.524		-0.407			

TABLE F-4. SIGNIFICANT CORRELATIONS EXISTING BETWEEN SPECIFIED DESIGN OPTIONS AND ITEMS OF BACKGROUND INFORMATION INDICATED FOR THE HUMAN RESOURCE COMPONENT - <u>DIFFICULTY</u>, SAMPLE OF 32 MAINTENANCE TECHNICIANS, 354th AVIONICS SQUADRON, MYRTLE BEACH, SOUTH CAROLINA, AUGUST 1974

	Background Information						
	Rank	Age	Asgn	Xper	Yrs Svs	Yrs Sch	Last 5 Yrs Exp
1A	0.451	0.503	0.378	0.460			
2A					0.413		
2B					0.392		
3A				0.484			0.474
3B					0.373		
5B	0.375	0.362		0.486			
6A					-0.436		
6B		-0.508				-0.485	

TABLE F-5. SIGNIFICANT CORRELATIONS EXISTING BETWEEN SPECIFIED DESIGN OPTIONS AND ITEMS OF BACKGROUND INFORMATION INDICATED FOR THE HUMAN RESOURCE COMPONENT - TRAINING REQUIRED, SAMPLE OF 32 MAINTENANCE TECHNICIANS, 354th AVIONICS SQUADRON, MYRTLE BEACH, SOUTH CAROLINA, AUGUST 1974

	Background Information						
	Rank	Age	Asgn	Xper	Yrs Svs	Yrs Sch	Last 5 Yrs Exp
1A				0.412			
1B						-0.431	
3A				0.392			
5B	0.369	0.386		0.458			
6A			0.458				
6B						-0.416	
8A				0.438			

TABLE F-6. SIGNIFICANT CORRELATIONS EXISTING BETWEEN SPECIFIED DESIGN OPTIONS AND ITEMS OF BACKGROUND INFORMATION INDICATED FOR THE HUMAN RESOURCE COMPONENT - EXTREME ENVIRONMENTS, SAMPLE OF 32 MAINTENANCE TECHNICIANS, 354th AVIONICS SQUADRON, MYRTLE BEACH, SOUTH CAROLINA, AUGUST 1974

	Background Information						
	Rank	Age	Asgn	Xper	Yrs Svs	Yrs Sch	Last 5 Yrs Exp
1A	0.356	0.401		0.399	0.428		0.531
2B	0.385						
3A				0.349			0.353
5A							0.353
5B				0.426			0.365
6A			0.412		-0.400		
6B		-0.443		-0.450			
6D							-0.441
8A				0.419			
8B				0.425			

TABLE F-7. SIGNIFICANT CORRELATIONS EXISTING BETWEEN SPECIFIED DESIGN OPTIONS AND ITEMS OF BACKGROUND INFORMATION INDICATED FOR THE HUMAN RESOURCE COMPONENT - TIME REQUIRED, SAMPLE OF 32 MAINTENANCE TECHNICIANS, 354th AVIONICS SQUADRON, MYRTLE BEACH, SOUTH CAROLINA, AUGUST 1974

	Background Information						
	Rank	Age	Asgn	Xper	Yrs Svs	Yrs Sch	Last 5 Yrs Exp
2A							0.386
6A					-0.515		
6B					-0.462		
6D	-0.531	-0.446	-0.505	-0.538			
8A							0.360